The magazine of aerospace technologies / MAY 1960

space aeronautics

Rec 3/16/60
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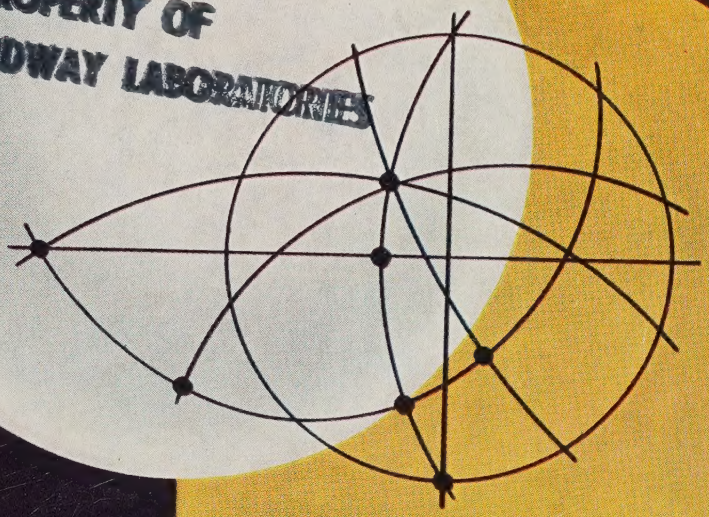
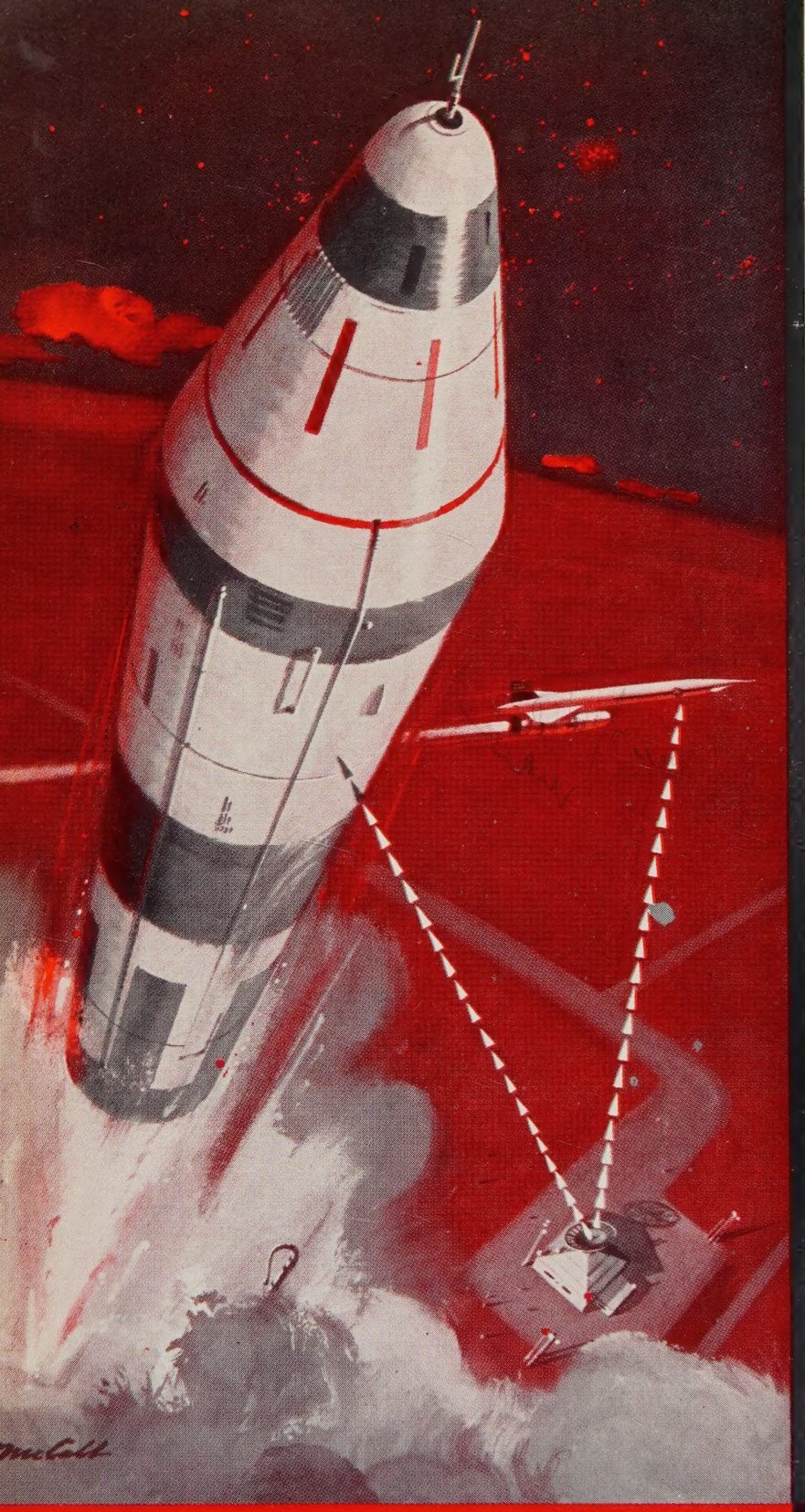


visualizing three-dimensional design problems

A CONOVER-MAST PUBLICATION



New from Crosley...

miniaturized

Command Receivers for missiles and drones

To meet the critical need for high-density packaging in missiles, Avco's Crosley Division has developed new miniaturized Command Destruct Receivers that weigh only three pounds.

Their task: To receive and act upon instruction from the ground to destroy a missile that has gone out of control.

In the Command Destruct configuration for range safety and similar applications, the miniaturized Command Receiver has four channels incorporating a decoder, to provide a secure link between the ground station and missile.

For high-performance drones and decoys, there are similar miniaturized Command Receivers that employ a 12-channel network. These receivers will actuate control surfaces, direct engine operation, and open a recovery parachute—all by radio-conveyed ground instruction.

Today Avco/Crosley Command Receivers are standard equipment on most of the nation's missiles. And by meeting the most severe environmental and operational requirements they have proved themselves for the future.

For more information, write to Vice-President, Marketing-Defense Products, Dept. C-CR, Crosley Division, Avco Corporation, 1329 Arlington Street, Cincinnati 25, Ohio

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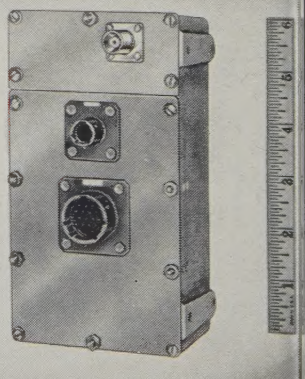
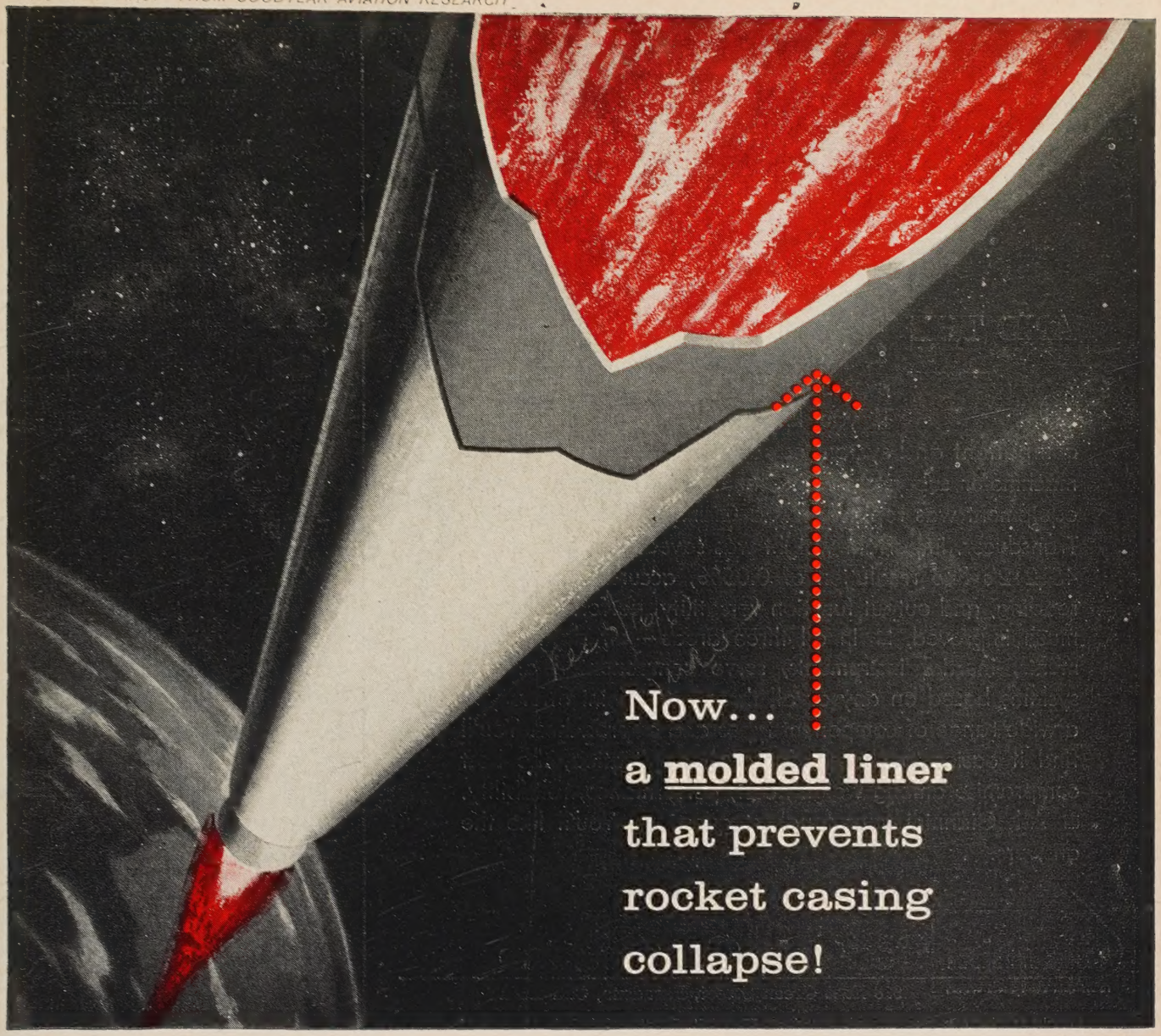
Avco / Crosley



New Crosley Command Receiver is about the size of a kitchen match box.



1. Keeping rocket casings from buckling under extreme thrust temperatures produced by our second-generation missiles was a serious problem. One solution: Increase casing thickness. But this imposes severe weight penalties. What was needed: A lightweight insulating material able to withstand heat up to 7,000°F. for as long as two minutes.

2. To meet this need, Goodyear has perfected a technique of *high-pressure molding* rocket liners from a new Navy-developed rubberlike compound. Goodyear's molding process on such rubberlike materials achieves unprecedented dimensional accuracy as well as the ability to duplicate this precise accuracy in succeeding production units. Result: A liner that is not only precisely true to specified tolerances but also free of voids and contamination. In use, the liner erodes away and is discharged in the tail blast, leaving no dead weight within the rocket.

3. Now being checked out for advanced missiles, this Goodyear liner makes possible thinner casings—bigger pay loads. Because it's molded, moreover, it can be formed to almost any configuration and degree of taper. Molding techniques for materials, as well as the development of new materials for use in difficult insulation areas such as in tail cones and nose cones for re-entry vehicles, etc., are now being evaluated at Goodyear.

For complete details, write on company letterhead or phone: The Goodyear Tire & Rubber Company, Aviation Products Division, Dept. Q-1714, Akron 16, Ohio, or Los Angeles 54, California.

AVIATION PRODUCTS BY

GOODYEAR

More aircraft land on Goodyear Tires, Wheels and Brakes than on any other kind

THE
INSTRUMENT,
THE
SYSTEM,

AND THE BUILT-IN TREND

Today's trend in avionics asks a lot. Simplification. Performance better than ever before. ■ Hard to reconcile? Not if you know about Giannini's helpful component and system capabilities. ■ Example: In a machmeter subsystem for a major prime, more complex equipment was replaced by a Giannini 451212 Pressure Transducer. Important weight was saved. Yet, because of 451212's fine resolution of 0.05%, accuracy to 1% of reading, and output function versatility, performance was much improved. ■ In all three areas — **air data instruments, inertial instruments, servo components** — and in systems based on any or all three — Giannini offers you a wide range of component types and approaches. You'll find it easier to choose, for each application, the best compromise among weight, cost, performance, reliability. ■ Ask Giannini your toughest questions. You'll like the answers.

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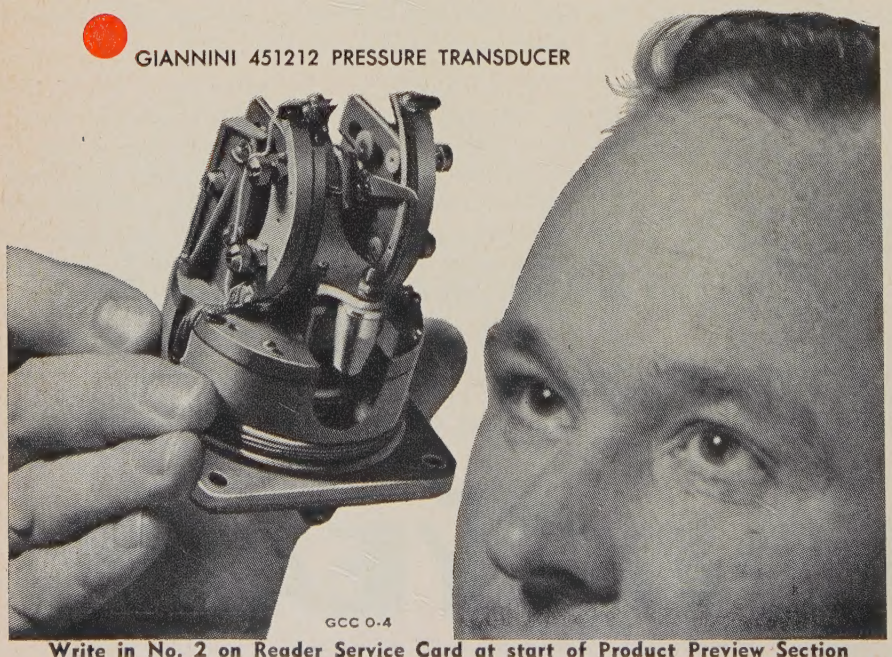
GIANNINI 451212 PRESSURE TRANSDUCER



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space/aeronautics

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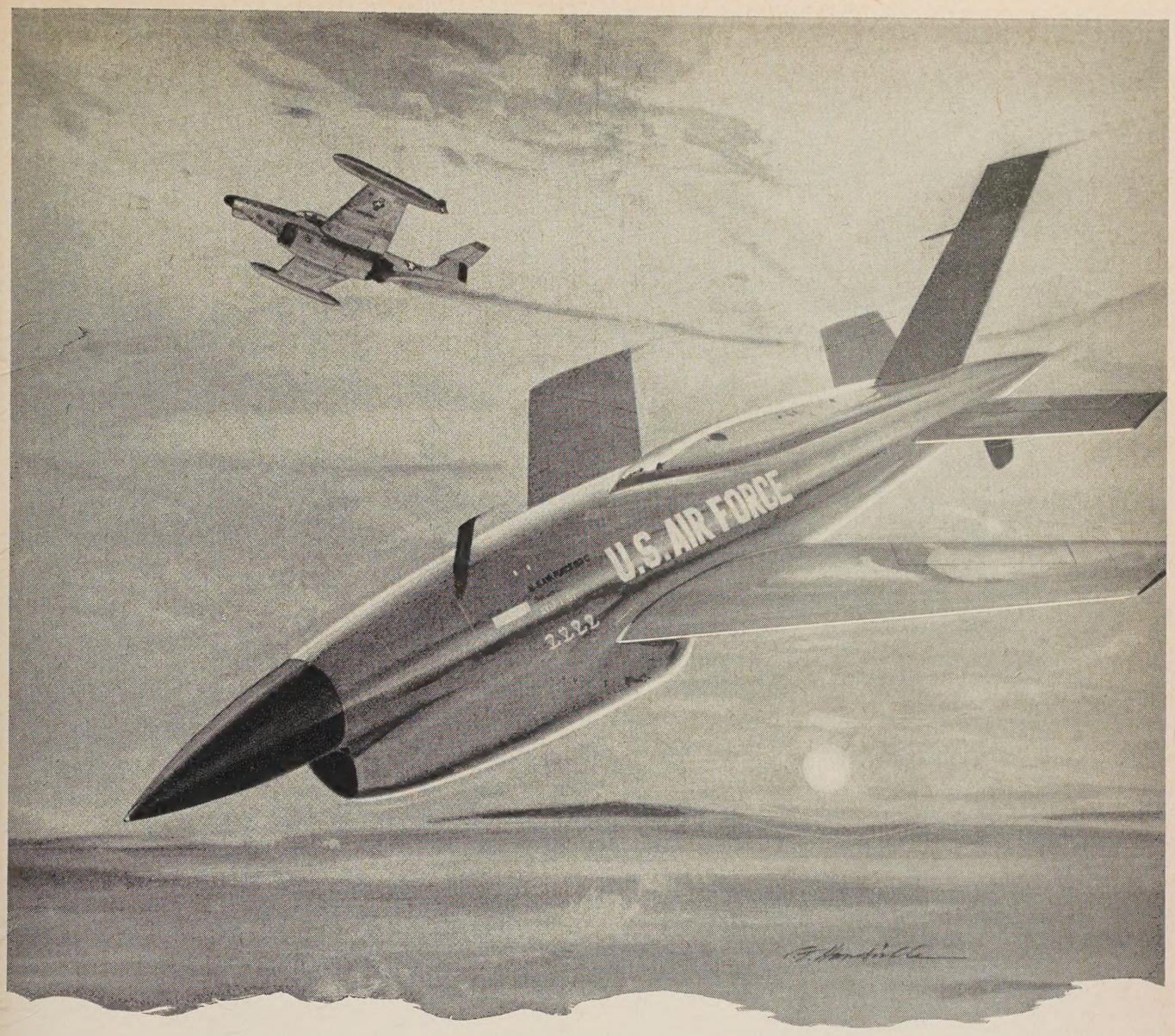

From an original painting for CECO by R. T. Handville

Contributing to the superb performance . . . of each Ryan Q-2C Firebee is a Continental J-69 turbojet equipped with single-package *engine control and fuel pump* engineered and precision-produced by Chandler Evans.

Products, too, are "known by the company they keep", and CECO is proud to be airborne with an array of important missiles as well as with many of the latest and finest military and commercial aircraft.

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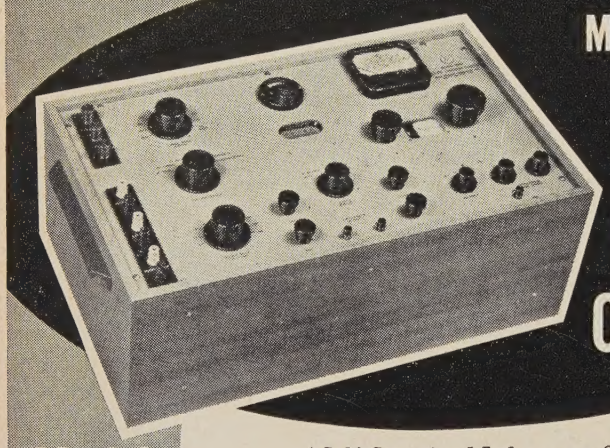
from

Instrument Calibration HEADQUARTERS

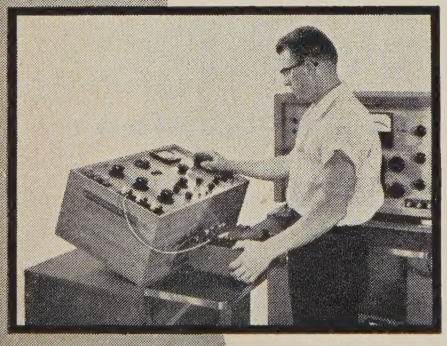


Measures Precise AC-DC Voltage & Current

Model 1605 $2450.

A Self-Contained Laboratory Standard Facility

The Model 1605 AC-DC Calibration/Transfer Standard is a multi-function instrument capable of measuring AC and DC voltage and current up to 1500 volts and 15 amperes. It includes a precision four-digit readout potentiometer, laboratory standard cell, precision voltage multipliers, precision shunts hermetically sealed in oil, light beam galvanometer, AC monitoring meter, thermal converter and all necessary batteries and controls. DC measurements utilize the potentiometer or the potentiometer in conjunction with the voltage multipliers or shunts. For AC measurements the potentiometer and/or multiplier-shunt arrangement is used with the compensated AC-DC transfer element.



LIMIT OF ERROR

DC: 0.05% with correction factors; 0.1% direct reading.

AC: 0.065% with correction factors; 0.13% direct reading.

(AC accuracies are to 50 kc on most ranges.)

For Owners of the RFL Model 829 AC-DC Instrument Calibration Standard

The Model 1605 may be used in conjunction with the Model 829 to calibrate instruments having greater accuracy requirements than that supplied by the Model 829 alone. The Model 1605 may also be used to calibrate the Model 829. The 829/1605 combination provides a calibration system which will handle your requirements, for current and voltage measurements to an accuracy of better than 0.1%, from DC to 400 cps.

Performance is rigidly guaranteed. Price is net, f.o.b. Boonton, N.J. and subject to change without notice.

SEND FOR TECH. DATA

For additional information, including application data, write or phone DE 4-3100. Demonstrations available by local representatives.

Radio Frequency LABORATORIES, INC. Boonton, New Jersey, U.S.A.

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cover story

What do you do when you have to solve a three-dimensional problem involving several coordinate systems? Most likely you start out by drawing an isometric or perspective diagram—and most likely, after you've drawn in four or five angles, you're staggered by the confusing mess of crossing lines in front of you. But it doesn't have to be this way, argues the article starting on *page 59,* the first in a two-part series on three-dimensional visualization. As a better solution, it proposes the use of stereographic projection—symbolized on our cover by artist Weimer Pursell—as a non-pictorial shorthand for getting three-dimensional problems down on paper.

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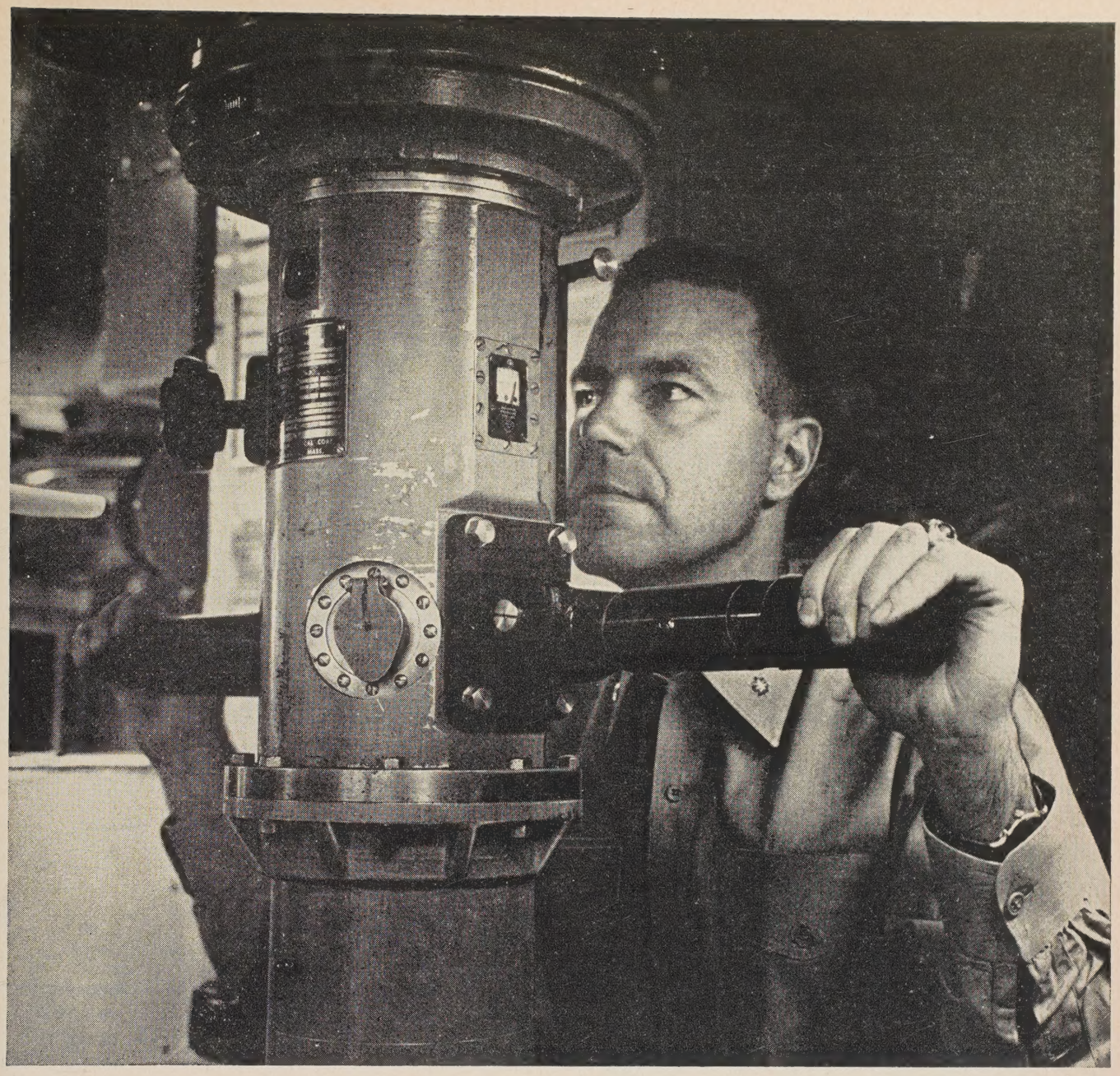


COUNTDOWN...at full fathom five

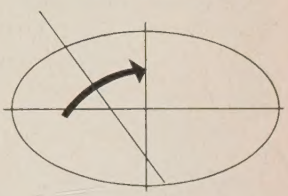
One day, a new fleet weapon system will be *on-station* beneath the ocean surface—ready to hurl retaliatory missiles toward strategic inland targets with pinpoint accuracy. This new weapon system will be part of the Navy's Polaris Fleet Ballistic Missile Program.

Though new in concept, the Polaris program makes full use of the precision Shipboard Inertial Navigation Systems (SINS) developed and produced by Autonetics for the United States Navy.

System design and components of earlier autonavigators have proved reliable in an Air Force supersonic missile, aboard the Navy's surface ship *USS Compass Island*, and on the *USS Nautilus* and *Skate*.

Advanced Autonetics' Shipboard Inertial Navigation Systems—like those to be used by the *USS George Washington*, the first Polaris-carrying submarine—will provide the critical missile alignment data to insure effective missile launching. SINS emits no tell-tale signals ... requires no receipt of external transmission at any time.

DID YOU KNOW?



The flattening of the earth at the poles can result in a navigational error of almost eleven nautical miles if not taken into account.

Inertial navigation by Autonetics

DOWNEY, CALIFORNIA

A DIVISION OF NORTH AMERICAN AVIATION, INC. • REGIONAL OFFICES: WASHINGTON, D. C. AND DAYTON, OHIO

INERTIAL NAVIGATION / ARMAMENT AND FLIGHT CONTROL / COMPUTERS AND DATA SYSTEMS

May 1960

space aeronautics

volume 33, number 5

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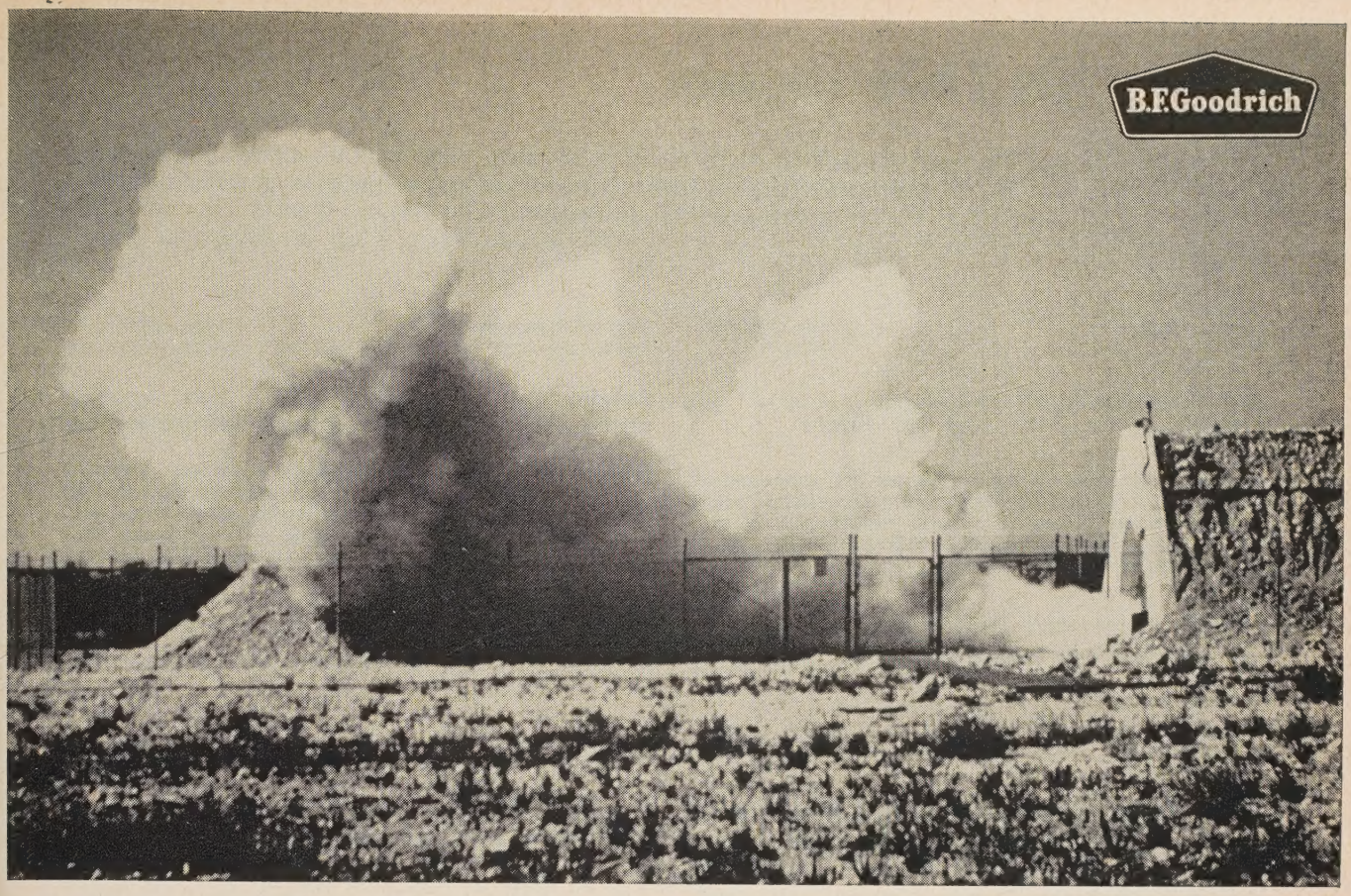


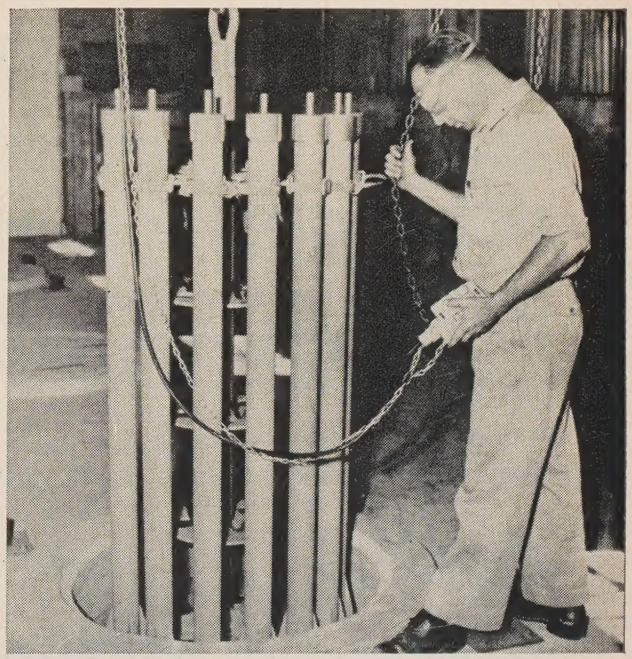
B. F. Goodrich producing high-energy solid propellants

This static test tunnel is one of the 56 specialized facilities at the B. F. Goodrich solid propellant plant, Rialto, California. BFG-made propellants are currently being processed and loaded in solid fueled rocket motors of the LOKI, RTV and ASP types.

B. F. Goodrich pioneered the development of the major polymeric binder-fuels now being used in our country's most advanced missiles... Liquid "C" synthetic rubber and polyurethane. BFG solid fuels are outstanding in their high energy performance, and have excellent castability, ideal physical properties at low and high temperatures, excellent burning characteristics and batch-to-batch uniformity.

B. F. Goodrich is qualified and equipped to handle complete rocket motor projects... from complete design through testing and shipment. BFG also produces rocket motor cases, case and nozzle liners and other parts in conjunction with complete propulsion systems. Test and production motors containing cast and case-bonded propellant grains in various sizes and weighing up to 2,000 pounds have been successfully manufactured and fired.

For complete information on how BFG solid propellant facilities can help you, write for a copy of the new booklet "B. F. Goodrich Solid Propellants for the Space Age". *B. F. Goodrich Aviation Products, a division of The B. F. Goodrich Company, Department SA-5, Akron, Ohio.*



Lowering a rack of small rocket motors into curing pit at the BFG Rialto plant after propellant has been poured into the cases. B. F. Goodrich has been engaged in composite solid propellant research since 1952—in motor production since 1957.

B.F.Goodrich aviation products

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in this issue

Here's a quick rundown of the technical information offered in the articles in this issue. You can also use these article abstracts to build up your own permanent record for reference in the future—just clip them, paste them up on standard three-by-five cards, and file them.

Aerospace Engineering
Propulsion

Astia code: 27-3
Your code:

Arc-jet and photon rockets: propulsion for near and far future

Survey of the state of the art in arc-jet rocket design and of the prospects for photon propulsion. Basic principles, important design problems (including electrode design and cooling provisions), and probable applications of the arc-jet type are discussed.

by Kurt R. Stehling, Contributing Technical Editor

space/aeronautics 33/5 (May '60) p. 42

Aerospace Engineering
Dynamics, Accessory Systems

Astia code: 12-1
Your code:

Solving 3-D problems made simple by stereographic projection

First article in two-part series on stereographic projection technique for visualizing and manipulating three-dimensional problems involving angles. Basic constructions needed. Problem assignments, and solutions are explained step by step. Presentation of vectors is outlined.

by Sidnet Godet, Reeves Instrument

space/aeronautics 33/5 (May '60) p. 59

Aerospace Engineering
Materials

Astia code: 17-4, -7
Your code:

State of the art: columbium and tantalum

Mechanical properties of these refractory metals and some of their alloys are discussed. Areas covered include tensile properties, oxidation resistance, and fabrication.

by Irwin Stambler, Associate Editor

space/aeronautics 33/5 (May '60) p. 46

Aerospace Engineering
Accessory Systems, Production Engineering

Astia code: 1-2
Your code:

Brazed joints, thin-wall tubing streamline B-70 plumbing

Description of design approaches taken by North American in tubing installation for B-70 hydraulic, fuel, and environmental systems. Methods by which tube joints are brazed in place are discussed.

by Irwin Stambler, Associate Editor

space/aeronautics 33/5 (May '60) p. 75

Aerospace Engineering
Accessory Systems

Astia code: 1-2; 12-1
Your code:

Non-propulsive power for advanced vehicles—III

Analyzes open- and closed-cycle fuel-cell designs; photovoltaic, static, and dynamic techniques of converting solar energy to electric power; and nuclear power systems. Gives status, optimum power ranges, duty life, advantages, and disadvantages of each design.

by Robert W. Curran, Boeing Airplane

space/aeronautics 33/5 (May '60) p. 52

Aerospace Engineering
Testing, Materials

Astia code: 30-3, -5
Your code:

100,000-atm pressures produced for materials studies

Description of compact high pressure apparatus built by National Bureau of Standards to study materials properties. The device can be operated by a conventional hydraulic press and produces pressures of 100,000 atm. Special setup for studies of electric resistance is also described.

by Randolph Hawthorne, Editor

space/aeronautics 33/5 (May '60) p. 93

Aerospace Engineering
Systems Engineering, Structures

Astia code: 2-1
Your code:

Pioneer V: first planet made in U.S.A. (Design Progress)

Detail photos showing structural features of Pioneer V. Sequence of photos showing payload being installed on third stage, with close-ups of solar cell paddle package in stowed position. Gives breakdown of payload weight and shows orbit in relation to the earth and Venus.

by Victor de Biasi, Associate Editor

space/aeronautics 33/5 (May '60) p. 55

Aerospace Engineering
Materials

Astia code: 17-4
Your code:

Boron: impressive properties, impressive problems

Discussion of state of the art in boron. Data on physical, electric, and optical properties are given. Outstanding problem areas in boron technology are described.

by D. N. Williams, Battelle Memorial Institute

space/aeronautics 33/5 (May '60) p. 101

To make filing easier, each abstract is coded according to the Astia Distribution Guide. Copies of this guide are available from Armed Services Technical Information Agency, Arlington Hall Sta., Arlington 12, Va. There is also room on the abstracts for you to insert your own key if you use a special coding system.

Aerospace Engineering
Propulsion, Production, Engineering, Materials

Astia code: 26-1
Your code:

Cheaper and lighter rockets with filament winding

Filament winding techniques for making liquid and solid propellant rocket engine thrust chambers are described as developed by Rocketdyne engineers. Production machinery is outlined. Further applications of the process discussed including pressure vessels and propellant tanks.

by Richard Gorcey, Rocketdyne

space/aeronautics 33/5 (May '60) p. 117

Aerospace Electronics

Astia code: 8-1
Your code:

Just how transparent is your radome?

The principal undesired effect of a radome on airborne weather radars are losses in maximum range and angular resolution. Both losses are analyzed, and simple mathematical expressions are derived to show their effect on radar performance.

by Dalton A. Bell, Convair-San Diego

space/aeronautics 33/5 (May '60) p. 170

Aerospace Engineering
Dynamics

Astia code: 2-1
Your code:

Finding the oblateness effects on satellite orbits

Report on a new method (developed by NBS) for determining the effects of the earth's oblateness on satellite orbits without perturbation theory. Fifteen equations are given to show the formulation of the method. Results of the method are shown to agree satisfactorily with observed values.

by Englebert Kirchner, Managing Editor

space/aeronautics 33/5 (May '60) p. 137

Aerospace Electronics

Astia code: 12-2
Your code:

Opto-electronic guidance for air-to-ground (Design Digest)

Design details of an optical-electronic guidance system based on an angular motion detector. System's optics are diagramed and described. Cutaway of mockup is shown, performance specs are outlined, and unique features are described.

by Bernard Kovit, Associate Electronics Editor

space/aeronautics 33/5 (May '60) p. 174

Aerospace Electronics

Astia code: 5-2
Your code:

Pioneer V's UHF link covers 50 million miles of space

The telemetry package and system of the Pioneer V payload are described functionally. Design details of the transmitters, the receiver, and the Telebit digital telemetry system are discussed. The solar-cell power supply and the temperature control of the electronics package are also reviewed.

by P. F. Glaser & E. R. Spangler, Space Technology Labs.

space/aeronautics 33/5 (May '60) p. 162

Aerospace Electronics

Astia code: 19-4
Your code:

Alignment trade-offs for in-motion inertial platforms

Develops a quantitative basis for evaluating trade-offs between accuracy and settling time in the alignment of an inertial platform in a moving vehicle. Results of a three-axis analog computer study are detailed to show the significance of initial conditions and vehicle motion.

by James E. Vaeth, Martin

space/aeronautics 33/5 (May '60) p. 179

Aerospace Electronics

Astia code: 8-2
Your code:

Hidden design factors for thermo-electric coolers

Analysis of design factors affecting thermoelectric cooling systems. Joulean heat loss, variation of the net refrigeration rate of a Peltier couple with current, and coefficient of performance are treated. Performance curves and typical cooler modules are shown.

by J. C. Carrol, Westinghouse Electric

space/aeronautics 33/5 (May '60) p. 166

Aerospace Electronics

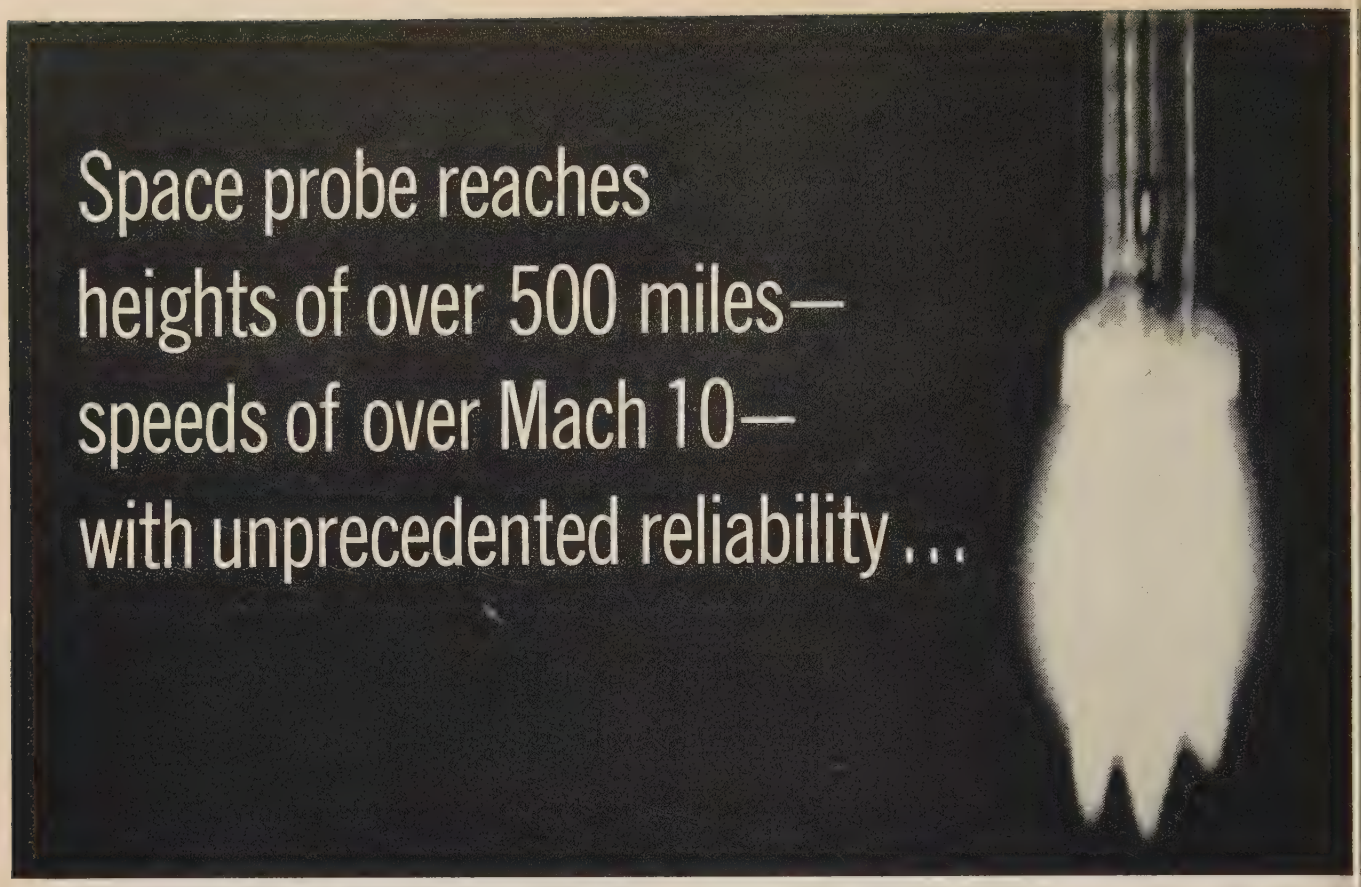
Astia code: 8-3
Your code:

Simple calculation gives radar's jamming susceptibility

Two approximate "reduction in range" formulas for a radar subjected to noise jamming are derived, and their use and limitations are discussed. An example shows how the formulas are applied. Range vs jamming curves and polar plots of susceptibility are given.

by Simon Cohen & George Minty, USA & U. of Washington

space/aeronautics 33/5 (May '60) p. 195



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One of the largest manufacturers of motive power units in the world, Bristol Siddeley Engines Limited produce the Gamma. A liquid propellent rocket engine, the Gamma powers the Saunders-Roe Black Knight, Britain's highly successful space research vehicle. An extremely reliable powerplant, the Gamma produces a total sea-level thrust of 16,400 lb (7,438 kg) and nearly 19,000 lb (8,618 kg) outside the earth's atmosphere, for a total powerplant weight of only 700 lb.

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Since Bristol Siddeley's rocket division began work in 1946, it has developed a wide range of components. By combining these components in single or multi-chamber layouts, thrust requirements from 500 lb up to 100,000 lb can be met.

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coming next month

VTOL, STOL, and ground-effect vehicles will be covered in SPACE/AERONAUTICS' special report. Highlights of this report will be three staff-written state-of-the-art surveys of developments and prospects both in this country and abroad and an article on the special design problems and of ground effect vehicles. In addition, there will be a market analysis and an extensive listing of existing models, giving detailed specifications and performance data.

BIG ROCKETS alone aren't enough for a big missile —just as essential are the little vernier rockets that help control the missile's attitude. Most spacecraft, too, couldn't get along without small rockets in the top stage or even in the payload itself. The special design problems of these rockets will be discussed in detail by Contributing Technical Editor Kurt Stehling.

HONEYCOMBS in structures have been advancing steadily—almost every new vehicle sets a new record for the use of honeycomb. What is behind this trend in terms of practical design and production? Associate Editor Irwin Stambler will answer this question in a report on the application of honeycomb in the structure of one of the most advanced current aircraft.

coming soon

SOME OF the most important people in spacecraft design never get anywhere near the hardware—they just work on paper and blackboard to figure out the orbit mechanics of the mission. Yet the results they come up with have a tremendous effect on hardware, since propulsion, guidance, attitude control, etc., all must meet the requirements set by orbit mechanics. A detailed survey will show what is involved in this relationship between theory and practice and how orbit mechanics makes the most of the equipment we can build.

CLUSTERING, it's become pretty obvious, is the answer to our need for super-thrust vehicles. It gets us around the tremendous problems of building gigantic single-chamber engines, but of course it also has its own set of troubles. How these are being licked will be outlined in detail by Kurt Stehling.

CRASH SAFETY is a goal that aircraft designers can never afford to overlook. A wealth of data on this subject, gathered in an extensive crash study program, will be reviewed, together with the design recommendations that came out of the program.

keeping in touch

3-D visualization made easy

DO YOU have trouble seeing relationships between quantities involved in three dimensions? For instance, in multi-gimbaled platforms of inertial systems? In resolution of angular velocities?

We do, too. At least we have trouble with these and similar relationships brought up by a brain at Reeves Instrument.

The way he explained it, it sounded easy—even to us—up to a point. For our technical readers who get involved in such problems more than we do, and who want to know his fascinating method, you will find Mr. Godet's article on 3-D visualization on *page 59*.

This is a very different type of article for SPACE/AERONAUTICS to publish. And, in an era when everything is getting more and more complicated in every way, this article refreshingly shows a way to make some things in your job simpler.

Because it is something of a change in editorial diet for SPACE/AERONAUTICS, our editors would be glad to hear what you think of it. Do you like it—want more of this type—or would you just as soon we forget it? Any suggestions of something else you would like to see published?

Speaking of suggestions, Editor Randolph Hawthorne says that returns from our reader preference survey are being evaluated by his staff, and they have found some very good suggestions. One, which quite a number of you put forward, was for more information in the VTOL, STOL, and ground-effect vehicle field. It so happens that a special report on the subject was already being planned at the time of the survey. The report will appear in the June issue.

Many suggestions showed that our editorial coverage now is considered the best among technical magazines. Some want us to do a better "packaging" of articles and ads so that material can be clipped easily for filing. All your suggestions are helpful.

S/A editor sets pattern for UCLA

It isn't often that a technical magazine editor sets the pattern for a university course, especially for so famous an institution as the University of California at Los Angeles. We are very proud therefore that one of our editors has received such distinction.

Last December, Victor de Biasi, GSE special report project leader, was invited to be the moderator at the IRE National Aeronautics Electronics Conference's GSE session in Dayton this month. The NAECON papers committee invitation to Vic explained:

"You have been invited to act as moderator because of your prominence in the technical area covered by the session." It went on to say that as moderator Vic could choose or invite the papers to be given at the session.

It was in the course of carrying out this mandate that Vic developed an outline of the GSE area to be covered, based on his wide knowledge of the field.

One of the replies to his invitation to present papers at the GSE session came from Space Technology Labs. It mentioned that UCLA had started a course on "Ground Support Systems for Missiles and Space Vehicles," and that this course would be nearly completed by the time the IRE NAECON meeting took place. Permission was asked to use Vic's outline for development of a second course in GSE at UCLA.

"I feel," said the STL correspondent, "that a second course related to the future requirements of GSE is called for and believe such a course should be patterned after your IRE conference outline."

Needless to say, we are extremely honored and happy that Vic's professional standing is so highly regarded in both the engineering and educational fields.

Following our special report on undersea weapon systems last January, our editors have continued to collect more data for further reports. The immediate objective now is to include a section on UWS in the annual R&D HANDBOOK.

Associate editor Bern Kovit, who is making this subject one of his specialties, was on his way to Woods Hole (Mass.) Oceanographic Institution as we wrote this to get a reading on the latest research material. We think his explanation to Woods Hole officials of our purpose is worth passing on to our readers.

Bern said he wanted to stress two important points:

- Our interest in oceanography stems from an increasing awareness of the extent to which engineers in our industry are becoming engaged in projects involving the undersea environments.
- Ours being a technical information service, our intent is to present information that will be both interesting and useful to our engineer readers. To this extent we are not so much interested in uncovering news scoops as we are in fostering the spread of scientific data and to direct more attention to the problems and achievements in this highly complex, vital field.

William L. Mann

Publisher

How to handle installations in the field

. . . without spreading your engineering staff too thin

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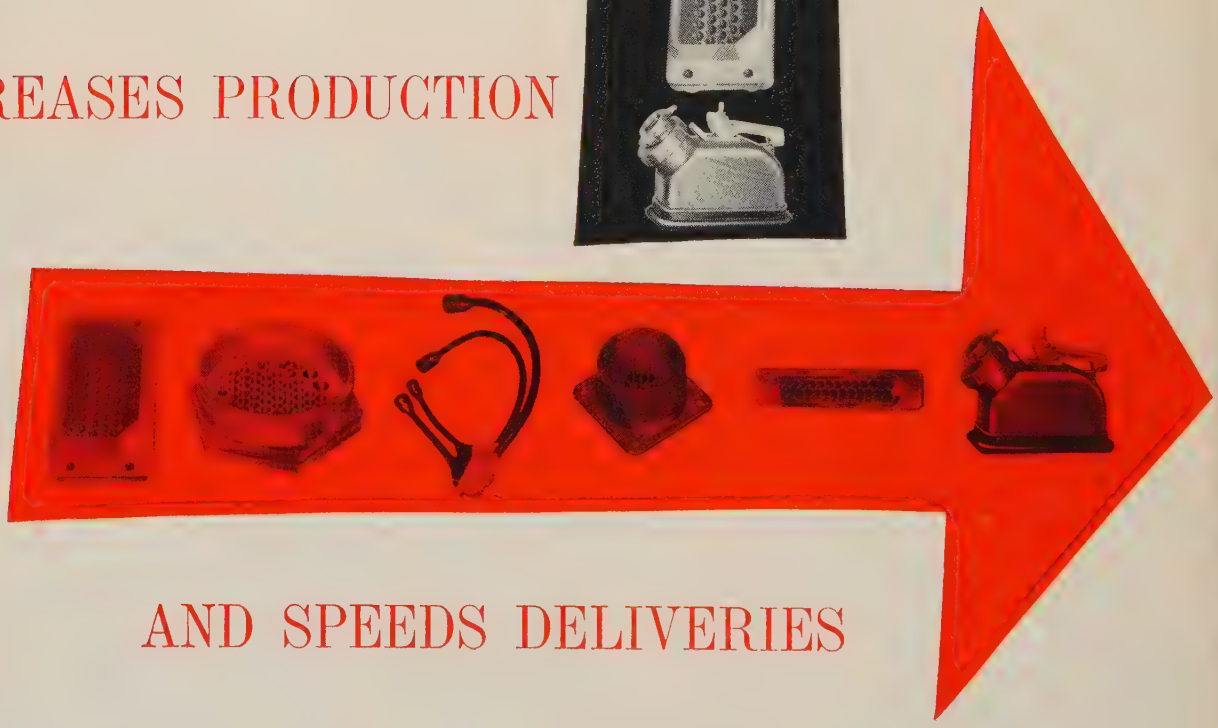

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editorial

Patents and progress

RIGHT OR WRONG, the opinion is growing that government has little respect for patent rights. Ironically, it isn't the big outfit that squawks out loud. It is the little fellow, who now is getting hurt most. Congressional committees, who think they help small business by restricting the patent award, had better take another look.

Someone in Congress might also look into procurement practices in getting the lowest prices for defense products. Everyone is for the lowest price we can get for defense. But who will stand up and say the government must rob industry to get it? This is what small business accuses the government of doing.

Strangely, small business has been Congress's fair-haired boy. Congressmen and senators often badger military procurement people to throw more bones to small business. Yet it is the small firms who are suing the government for robbing them of their patent rights.

NOW MAYBE the government is clean. Maybe there is a wrong idea spreading through U.S. industry. Maybe the advisory telling the Defense Department not to let potential patent infringement get in the way of knocking down a price doesn't mean what it seems to mean.

If it doesn't, then the General Accounting Office, which issued the advisory, and DOD, which acts on it, had better tell industry exactly what the policy does mean. And spell it out to the DOD bureaucrats who handle contracts.

Does the policy mean a flagrant disavowal of proprietary rights and an usurpation of patent grants? If not, then why do some 230 independent small firms—not to mention bigger defense companies who keep their mouths shut—have the idea it does?

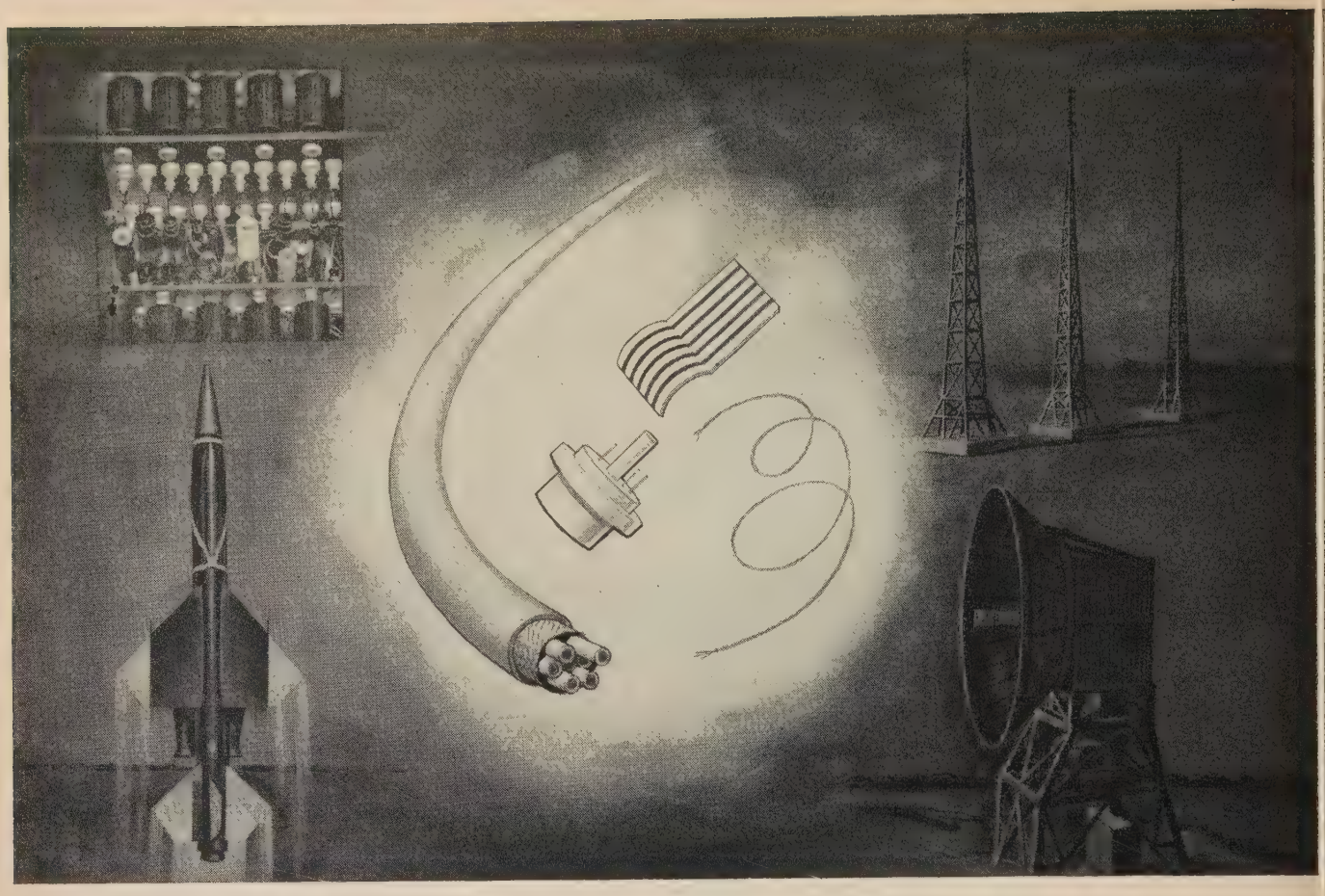
PATENTS aren't merely rights. They are incentives. An incentive can be either a kick in the pants or a carrot. We favor the carrot approach, which provides both a promise and a reward. Without patent protection, closely and fairly observed, product development will slow down. Without progress, not only will defense programs wilt, our whole economy will sicken.

The patent system has two important functions, from the public's viewpoint. These are to encourage research and initiative. On industry's side, ideas are the lifeblood of business. Unless they can be patented, ideas are up for grabs.

Government practice on patent rights is killing incentive. It is discouraging research. Hundreds of firms now have rigid policies against accepting government R&D contracts. Their number is growing. This trend must be reversed if we are to meet the technological threat of the Soviets. Proposed changes in the 1958 Space Act are only a step in the right direction.

Critics often call for "bold imagination" in national affairs. Their big blue eyes are on the golden horizon. But the patents issue right underfoot can determine how far and at what speed we keep moving toward Utopia.

Randolph Hawthorne, Editor



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And because TEFLON FEP-fluorocarbon resin is melt-processible, it can be extruded as jackets for wire and cable . . . as long, continuous lengths of wire insulation . . . and rapidly fabricated into complex shapes.

The new opportunities for improved design offered by TEFLON FEP resin are particularly important in aeronautic and space applications . . . wherever there is a premium on the utmost reliability, simplified assembly, savings in weight and space through miniaturization.

For more information about the properties and applications of TEFLON fluorocarbon resins, including additional data on the characteristics of the new FEP resin, write to us, mentioning your field of interest. Address: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept.T-65, Room 2526, Wilmington 98, Delaware.

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washington briefing

by A. N. Wecksler and R. M. Loebelson, Washington Bureau Chief & Associate Editor

A single space agency?

TWO NEW documents now circulating in Washington, one public and one secret, point up the divergent views over whether space research should remain split between DOD and NASA or whether a single agency should handle the entire project.

One is a House bill (HR 9675) designed to define the space roles of the military services and NASA. This proposed measure is getting strong support from DOD, especially USAF. Air Under Secretary Joseph V. Charyk says the bill "recognizes that the concept of a single program embracing military as well as non-military activities is illusory and that the concept of such a civil-military program in an isolated sense is not reasonable."

The bill is also being advocated by ARDC's commander, Lt. Gen. Bernard A. Schriever, as one that "will provide a clear authority for the DOD to conduct R&D and systems procurement in space necessary to the national defense." He maintains that those who recommend the establishment of a single, monolithic space agency "simply do not understand" the difference between military and civil space missions.

On the other hand, William M. Holaday, one-time Pentagon missile czar and current head of the soon-to-be-abolished DOD-NASA space liaison committee, is all for centering space research in NASA. He wants a "watchdog" manager of space programs, preferably NASA's administrator but possibly a DOD space official.

While the House Space Committee and other Congressional groups hold hearings on the validity of two space programs, DOD segments are busily trying to carve out important and permanent activities in space. A new 35-page USAF booklet, labeled "Advanced Military Systems" and classified "secret," outlines many upcoming projects, including armed interplanetary space ships and the use of the moon as a missile-launching base.

Best clue to USAF's attitude on the military use of space has come from Maj. Gen. Leighton I. Davis. AF's Assistant Deputy Chief of Staff for Development confidently predicts that the U.S. is on the verge of a breakthrough into military space operations. Within a decade, he says, "Travel in space will be easier from the standpoint of vehicle propulsion and stress problems than similar operations in the atmosphere."

Similar confidence is expressed by Maj. Gen. O. J. Ritland, head of ARDC's Ballistic Missile Division. He maintains the U.S. is "already well beyond the Buck Rogers era of science fiction. Space is with us, and we must get with it if we are to reap the advantages there."

The classified AF booklet, which is also being routed to aerospace industry R&D officials, is designed principally to pinpoint USAF's claim to being the nation's primary aerospace force and also to condition Congress and the public to the need for more space funds in forthcoming defense budgets.

For the immediate future, USAF is looking for more space research dollars for such programs as Dyna-Soar and various satellite and antisatellite systems. High-ranking AF research men contend that the development of important space vehicle systems — e.g., boosters and guidance — must move along faster than NASA's "crawl-before-you-walk" program.

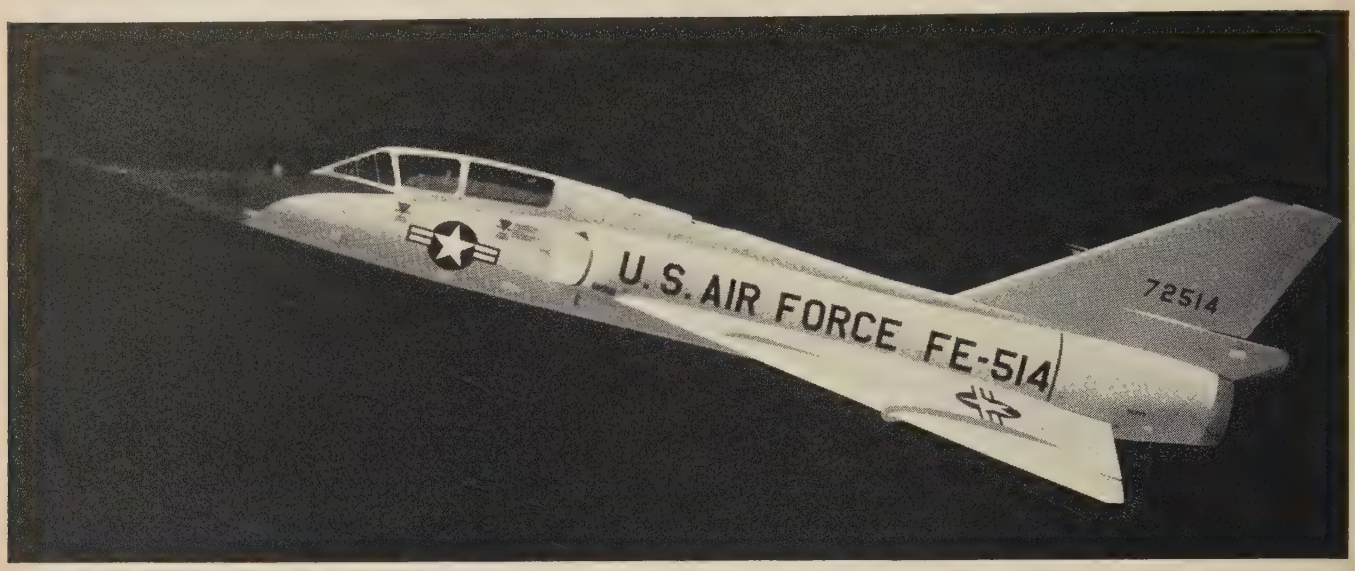
• • •

Improvements in cost, efficiency and performance are possible in GSE. This is the central theme of a report on a Department of Defense study group on ground support equipment for guided missiles.

These improvements can be achieved through a series of changes in policy and procedure. The report's first recommendation is for an improved

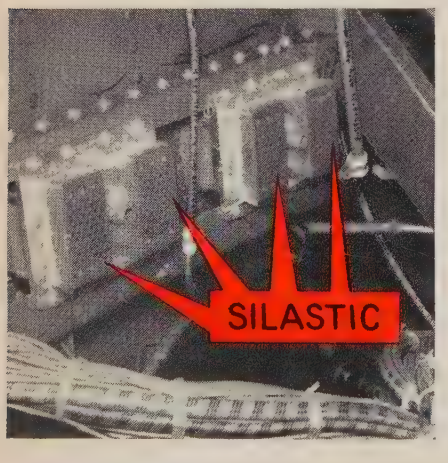
more on page 21

Many Parameters, One Elastomer



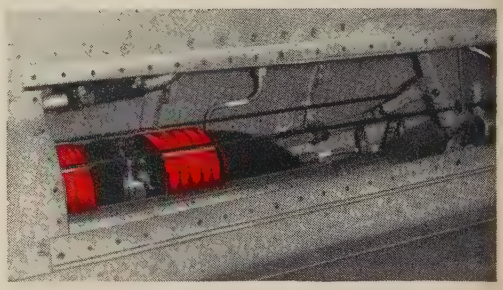
SILASTIC® SILICONE RUBBER meets varied specs in Convair F-106

When you're calling out materials on a plane or missile, isn't it a help to have one material that can meet a variety of rubber needs? A material that's been proven in all flight regimes? Engineers at Convair San Diego, Div. of General Dynamics Corporation found it so. The material is Silastic, the Dow Corning silicone rubber, and they specify it for many applications aboard the Mach 2-plus F-106 all-weather interceptor.

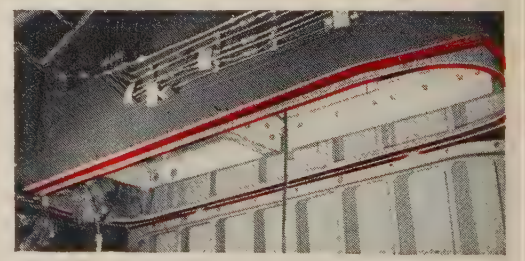


A few of the uses are illustrated here. At left you see molded parts . . . plug connectors used for checking out instrumentation. Located in the aft missile bay, they are subject to high flash temperatures during rocket firings. The reliability of Silastic in this part is reported excellent, with no failure even in the presence of chemicals or exhaust gases. (Wire bundle clamps are also of Silastic.)

A completely different application of Silastic is shown at right top: one of many connectors in the air bleed system. All connectors are covered with a flexible bellows of glass-reinforced Silastic. The duct beneath carries air at 800 F, and though there is insulation between steel duct and cover, the Silastic must still tolerate high temperatures while retaining its rubberiness and sealing ability.



Among other seals of Silastic aboard the F-106 are these hollow extrusions on the air-conditioning compartment door. They withstand severe temperatures, maintain a firm air-seal after extended lengths of time under compression.



Silastic stays rubbery from —130 to over 500 F; resists aging, weathering, oxidation. Your rubber parts supplier will engineer a part made of Silastic to add reliability to your design. For name of nearest fabricator or more data, write Dept. 0705.

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system of interchange of knowledge. This would provide for indexing of all data in research, science, and product engineering as well as for periodic symposia on subjects of interest and to be conducted by the Office of the Director of Defense Research and Engineering.

The report recommends that clearance for "need to know" should be made more flexible, and interchange of security information between contractors working on different programs and for different military departments should be encouraged. In R&D programs, the effort should be concentrated on the overall area of need, which would eliminate random attempts to design better items for each missile.

Paperwork should be kept to a minimum. Where possible, there should be:

- a single, overall Department of Defense spec for any given item;
- wider permissive use of industrial standards, specs and tests;
- wider use of performance specs.

The report recommends that the technical services of a single military agency be used on a specific project, rather than those of several agencies. It also suggests that the rotation of military personnel during the life of a project be held to a minimum.

Many contractors complain that GSE is ordered late. The report recommends that GSE be in phase with the missile schedule, and that experts be consulted early.

Where possible, the report recommends, the final production contract should be awarded to the company that did the R&D and design work. It also points out that a company's technical competence and experience in the field should carry great weight in the award of a contract.

The report further recommends that at the end of each phase — R&D, prototype test, and the first production run — all organizations involved in the project should present studies aimed at improvements in weight, simplicity, cost, etc. Unsatisfactory-equipment reports should be fully and promptly distributed, with requests for statements on these reports by the contractor. On the problem of lead time, a special DOD study is recommended.

• • •

Special characteristics of the aerospace industry were cited at a recent Washington session of the Electronics Industries Association:

- The aerospace industry is a fluctuating industry — much more so than the non-defense industries and other segments of the defense industry.

- **The industry is large — it accounts for the largest slice of the $17-18 billion spent yearly for military hardware and R&D.**

- The growth rate of the aerospace industry will become the highest among the defense industries.
- A changed product mix is a major characteristic of the industry. Electronics and propulsion are becoming the major segments.
- **The research-to-production has changed and will continue to shift in favor of research. As a result, consideration must be given to increasing the profit yields in R&D.**

- While the aerospace industry runs fewer risks as it invests in materials and equipment, it has problems maintaining the technical quality of its staffs and facilities. It therefore needs reasonably stable contract support.
- Production operations and processes are highly specialized —geared to the needs of specific end products. Staffs and facilities cannot be easily diverted to new, less specialized products.
- **While there once was a relative lack of interest in the aerospace industry on the part of outsiders, now there are a large number of well-managed and capable companies interested in the industry.**

• • •

In explaining ARDC's new development planning philosophy, reflected in the recent reorganization of BMD, WADD, and AFCCD (AF Command & Control Development), Col. E. C. Lavier, from the Office of the Deputy Chief of Staff for Plans, noted that proposed weapons systems are analyzed according to a "technological force structure plan." He added that a force projection taking into account all existing and conceivable weapon systems is planned for at least the next 20 years.

Systems are analyzed first in terms of the basic laws of physics and then to get an idea of the mix of vehicles or concepts with similar theoretical capabilities that will be available at any time during the projection period. The hypothetical systems that survive all these screenings would then get applied research support. A "planning objective" (PO) is thus defined that sets a reasonable date by which the applied research should result in an operational system.

W. M. Willis, Chief Engineer of Marman Division, displays some of the many couplings and joints developed by Marman engineers.

MARMAN

Leads in Joint and Coupling Engineering

Pictured at the left are a few of the many V-Band Couplings and Joints designed and produced by Marman for every aircraft and missile application. Marman V-Band Couplings are ideal for connecting all sizes of tubing, piping and ducting used in fluid transfer and structural applications. The lightweight Marman J13 V-Band Joint provides efficient sealing for pneumatic and hot air or gas lines. The J11 V-Band Joint may be used for fluid systems Marman high-performance CONOSEAL Joints provide a leakproof seal where zero leakage is required over a wide temperature range.

Call on Marman's 20 years of experience when you have a joint or coupling problem. Highly skilled and experienced engineers are ready to be of assistance to you. Also send for the new Marman Catalog No. 800 showing hundreds of joints available from stock.

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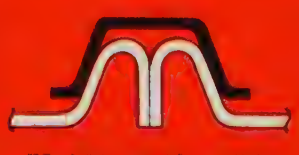
Standard V-Band Couplings and flanges for high-strength structural connection of components and tubing, choice of solid or formed flanges.



J13 Joints provide a lightweight connection for standard and thin wall tubing where low leakage rate is permissible.

J11 Joints for fuel connections where zero leakage is not required, as well as lube, air and gas lines for temperatures up to 1000° F., pressures to 4000 psig.

CONOSEAL Joints provide zero-leakage connection of tubing and piping over temperature range of —300° F. to +2000° F., pressures to 20,000 psig.

Wide range of products on display at Design Engineering Show, May 23-26, New York—Booths 1809 and 1908.

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Boosts for Atlas and Polaris approved by White House

PRESIDENT EISENHOWER'S proposals to increase the Polaris and Atlas programs are being hailed on Capitol Hill as steps in the right direction. But some Congressional critics maintain that these defense budget revisions are certainly too little and perhaps too late.

The President has approved plans to:

- *Provide funds for long-lead-time items for at least six more Polaris-firing nuclear subs.* The previously submitted fiscal '61 budget called for full funding for three such subs (to bring the total to 12) and partial funding for another three. The net result now is that at least 21 Polaris subs will be in the works, including nine funded only for long-lead-time items. Polaris missile production is also to be boosted as a result of the President's action. The Navy's long-range program calls for 45 Polaris subs.
- *Increase the number of missiles in the last six Atlas ICBM squadrons.* USAF plans originally called for 13 such squadrons, each equipped with 10 ICBMs. The first seven squadrons will still have 10 missiles each, but the last six will have 13 each—the Atlas force will now consist of 188 instead of 170 missiles (plus spares). No action was taken to increase the Titan program (14 squadrons and 140 missiles).

THE DOD-WHITE HOUSE modifications in the '61 defense budget (which will certainly be approved by the House and Senate Military Appropriations Subcommittees) will result in a boost of only $39 million over the $40.6 billion already requested for DOD activities next year. The reason for this small increase is that most of the funds needed for the Polaris and Atlas speedups will come out of other programs. Among these are:

- a $381 million cutback in production plans for the Boeing Bomarc B;
- reductions in spending on the Sage system and other continental air defense items;
- cancellation of two of the three anti-sub submarines in the original '61 defense program.

Only one Thrasher sub to be ordered with '61 money

DOD WILL SAVE $114 million by not going through with planned orders for two nuclear Thrasher-type subs with '61 money. The Navy intends to order four of these attack subs in June (with '60 money). Defense Secretary Thomas Gates believes the single Thrasher-type sub to be bought with '61 cash will provide for an "orderly" construction rate.

THE MOST INTRIGUING aspect of the speed-up in the Polaris program is that it may well be followed in the fall by a request for supplemental funds. First tests of missile-armed Polaris subs are due in September. If these prove successful, the Navy and DOD will be asking Congress for more money to start construction of some or all of the nine subs partially funded in the budget now before Congress.

More funds for space projects and B-52 alert may be sought by Congress

ALTHOUGH CONGRESS will certainly approve the revised Atlas and Polaris programs, there will be opposition from such lawmakers as Rep. George Mahon, of Texas, and Sens. Henry Jackson, of Washington and Stuart Symington, of Missouri, against the proposed cuts in the hunter-killer sub program. They (and other critics) may also try to provide additional funds for USAF space projects (the Samos and Midas satellites) and a large down-payment on a continuous B-52 airborne alert.

Secretary Gates says the '61 budget is already being shifted around to provide more money for AF's space program, but many lawmakers will probably insist on trying to speed the Samos recon and Midas ICBM-detecting satellites even more. The B-52 airborne alert program (as modified by SAC Commander Gen. Thomas S. Power) would require $571 million in '60 and $850 million in '61. The President's budget message asks for about $85 million for the B-52 alert program. General Power feels the added money would make it possible to keep 25 per cent of SAC's Stratofortresses in the air at all times.

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EXTENT OF AF'S R&D spending on military satellites has been revealed for the first time. Air Force Secretary Dudley C. Sharp says that, in fiscal '61, $256 million, or nearly one-fifth of a total of $1.33 billion allocated for research, development, test, and evaluation, will go for development and testing of Discoverer, Samos, and Midas.

Almost exactly the same amount went to Lock-

more on next page

heed's Missiles & Space Division during the past two years for work on the three programs: Lockheed says it has gotten $273 million in USAF contracts during that period for space projects, including $157 million for Samos, $60 million for Midas and $56 million for Discoverer.

FLOOR FIGHTS are expected in the House and Senate before Congress adjourns on the government's right to inventions developed under military contracts. In the House, the battle is expected on an amendment liberalizing NASA's patent policies. The House Science and Astronautics Committee has approved a subcommittee recommendation that would bring NASA's patent policies close to those of the Defense Department.

Under the 1958 Space Act, NASA's patent policies were extremely rigid. In almost every case, NASA was supposed to take title to inventions. The proposed revision still requires that NASA get an irrevocable royalty-free license on all inventions developed under R&D contracts.

The floor fight is expected to be put up by Representatives who believe the U.S. is not safeguarding all its rights. Among those expected to oppose the new provision when it reaches the House floor are Reps. B. F. Sisk (D., Calif.) and James Quigley (D., Pa.). As written now, the measure has the support of DOD, NASA, AIA, and other industrial trade groups.

Interference with data dissemination is seen

IN THE SENATE, the floor fight may come on a different point but will also involve the principle of limiting U.S. control over patents on R&D work. The Senate Judiciary Subcommittee on Patents believes DOD patent clauses (in the Armed Services Procurement Regulation) may be holding back the dissemination of basic research data.

Sen. Joseph C. O'Mahoney (D., Wyo.) and his patent group contend that the provision giving commercial rights to an invention to the contractor who developed the invention holds up disclosure of the data to anyone until the contractor has taken steps to obtain a commercial patent. This, O'Mahoney believes, may hurt the defense effort even if the information that's withheld is primarily basic research data.

O'Mahoney has introduced S.3156, a bill that would restrict patent grants. It would require the Justice Department and the National Science Foundation to review R&D contracts before a clause granting exclusive commercial rights could be inserted. Formal release of these rights would be necessary.

O'MAHONEY'S BILL stems from a Justice Department study of patent practices under present R&D contracts. Justice recommended that the U.S. take title to all inventions, except in special cases approved by the U.S. Patents Administrator and the head of the agency administering the R&D contract.

This approach was rejected by the House Space Subcommittee as "specious". Noting that it had thoroughly investigated the contention that the U.S. should automatically retain patent rights, the House group said, it was "not impressed with this argument *per se*. If Federal ownership of inventions produced under NASA contracts gave the Government an advantage it does not receive from an irrevocable royalty-free license, if it normally enhanced the public interest, if it actually stimulated commercial use of the invention—then the 'Government pays, Government must own' concept would indeed be valid. Inquiry, however, shows that in the heavy majority of cases, NASA ownership would accomplish none of these things."

Representatives say industry should get patents that are commercially promising

THE HOUSE SUBCOMMITTEE takes the attitude that the contractor should be granted patent rights if the field being explored is so related to commercial endeavor that "inventions likely to result would have substantial promise of commerce utility and their early development would be apt to benefit the national economy."

The U.S. should retain patent rights, the House Space Subcommittee holds, if studies involve fields concerning health, safety, and welfare "and the inventions likely to result would be useful directly in such fields, and the public interest would best be served by making such inventions available to all to produce or use without payment of royalties."

•

MATS' MODERNIZATION PLANS call for the purchase of 94 swing-tail jets and 188 "workhorse" aircraft. The jets will cost about $4.5 million each; the "workhorse" planes (possibly turboprop cargo-liners) $8.5 million each. If MATS gets a Congressional go-ahead on its program,

more on page 26

CASE HISTORIES

Special high-temperature, full complement N/D ball bearing, made of cobalt base alloy, operates successfully at high temperature with no need for lubricant protection!

Photo: Courtesy Stratos Division, Fairchild Engine and Airplane Corp.

Special Alloy Ball Bearings Keep Butterfly Valve Modulating at 900° F.!

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Require highly heat-resistant ball bearings for butterfly valve which modulates 900° F. hot air blast in turbine air bleed. Despite radial loads up to 300 lbs., shaft must turn effortlessly through 65°.

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Extensive testing proved that this N/D equipped modulating system, currently used on the Lockheed Hercules C-130A, military transport, operates at required standards of performance and reliability . . . and without lubrication! In addition, other New Departure ball bearings, selected for their unsurpassed reliability, are used to support the turbine main shaft which operates at 45,000 rpm.

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it will need about $250 million a year for eight years.

LOCKHEED IS LOOKING at ways to modify its turboprop Electra airliner into a medium-range jet transport. Its plans call for the use of four aft-mounted jet engines.

PRODUCTION RUN of the 200-mile-range Bomarc A now exceeds 100, Boeing reports. An additional 100 experimental and service-test Bomarcs (including XIM-99Bs) have been delivered to USAF.

Republic buys into Holland's Fokker Aircraft

REPUBLIC AVIATION bought a "substantial" minority interest in Holland's Fokker Aircraft. The arrangement will not affect the output of the Fokker F-27, being built in the U.S. by Fairchild.

•

GRUMMAN RECEIVED a $21 million Army contract to deliver 42 AO-1 Mohawk airframes. The observation plane uses two Lycoming T53 turboprops. Other new contracts include $52.3 million for the A2F-1, $47.5 million for the W2F-1, and $28.7 million for the S2F-3.

SIKORSKY GOT a $45 million follow-on order for HSS-2 anti-sub copters. The contract will extend the production of the shaft-turbine-powered copter until December '61.

BuWeps, acting for USAF, gave Pratt & Whitney $45.6 million in orders for the J75-19W and J52-3 turbojets. The J75 is used in the F-105 and the F-106 and the J52 in the Hound Dog air-to-surface missile.

ARMY IS PLANNING to hold a competition later this year for a turbine-powered observation copter. The craft will be smaller than the present H-13, cruise at 126 mph, and have a 400-lb payload. It will replace the Bell H-13, Cessna L-19, and Hiller H-23. Production will begin in '64 or '65 after two test designs have been evaluated.

GE REORGANIZED its defense and electronics departments. The Electronic & Flight Systems Group, headed by C. W. LaPierre, replaces the former Electronic, Atomic & Defense Systems Group. It includes the Defense Electronics Division (Syracuse, N. Y.), the Electronic Components Division (Owensboro, Ky.), the Flight Propulsion Division, and the Aircraft Nuclear Propulsion Department (both at Evendale, Ohio).

ALLISON RECEIVED an $11.6 million contract for three versions of the T56 turboprop. The order calls for 83 -7s, 12 -8s, and 34 -10Ws.

CONVAIR-POMONA got a $5.5 million contract from the Army for development of the Mauler battlefield air defense missile system. The solid-fuel, radar-guided Mauler will be used against enemy tactical aircraft and also against short-range ballistic missiles. Overall development of the Mauler system is handled by the Army Rocket Guided Missile Agency at Redstone Arsenal, Ala.

THIOKOL RECEIVED a $2 million Navy contract to develop Guardian III prepackaged liquid rocket engines.

ANOTHER PART of the B-70 program has been reinstated. USAF told IBM to renew development of the B-70's bombing-navigation missile guidance system. Project is believed adaptable to other new USAF weapon systems.

Manufacturing development contract to Bell

BELL AIRCRAFT got a $1.4 million AF contract to develop manufacturing methods for insulated, double-wall cooled structures. These would enable space vehicles to survive re-entry.

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ROCKETDYNE RECEIVED a $4.5 million Army contract for design and development of the H-1 rocket motor for Saturn.

LEAR GOT a $2.3 million follow-on subcontract from Bell Telephone Labs for development of gyroscopic control instruments for Nike-Zeus. Since March '57, Lear has received a total of $9.3 million in subcontracts for this program.

LYCOMING received an AF contract totaling $11.1 million for T53 shaft turbines—the -3, being bought for the AO-1, and the -1A for the HU-1A copter.

GE-LYNN WILL SUPPLY 204 T58-8 shaft turbines for the HU2K-1 and HSS-2 copters under a $5.5 million contract. Another order totaling $8.3 million calls for 143 J85-5s and 143 J85-7s. These jet engines are used on the T-38A trainer and the GAM-72 Quail missile.

When crews of SAC's 1st Missile Division successfully launched the USAF ICBM Atlas from Vandenberg Air Force Base, September 9, 1959, the world became aware that the United States had brought into being a formidable retaliatory power for peace. Within four months after the first operational launch, the Air Force doubly underlined this missile's capability. On a single day, January 26, 1960, the 16th and 17th consecutive successful Atlases were fired intercontinental ranges to predetermined targets from both Atlantic and Pacific bases.

After only five years of intensive development, including concurrent research, testing and fabrication under this nation's top military priority, Atlas is extremely versatile as well as powerful. It was the Project Score satellite vehicle and is scheduled for use in Project Mercury, the Man in Space Program, and in other space exploration missions. Thus, used as a booster for space projects, Atlas provides the nation with a key capability in scientific as well as military applications.

Space Technology Laboratories provides the systems engineering and technical direction for the Atlas as well as other portions of the Air Force Ballistic Missile Program. Much of what was learned in building Atlas has helped cut the lead-time in the development of such other Air Force Ballistic Missiles as Thor, Titan and Minuteman.

Among the industrial organizations which have worked in concert in developing Atlas are such major contractors as: Convair, Division of General Dynamics Corp. for airframe, assembly and test; General Electric Co. and Burroughs Corp. for radio guidance; Arma, Division of American Bosch and Arma Corp. for inertial guidance; Rocketdyne Division of North American Aviation, Inc., for propulsion; General Electric Co. for re-entry vehicle; Acoustica Associates for propellant utilization.

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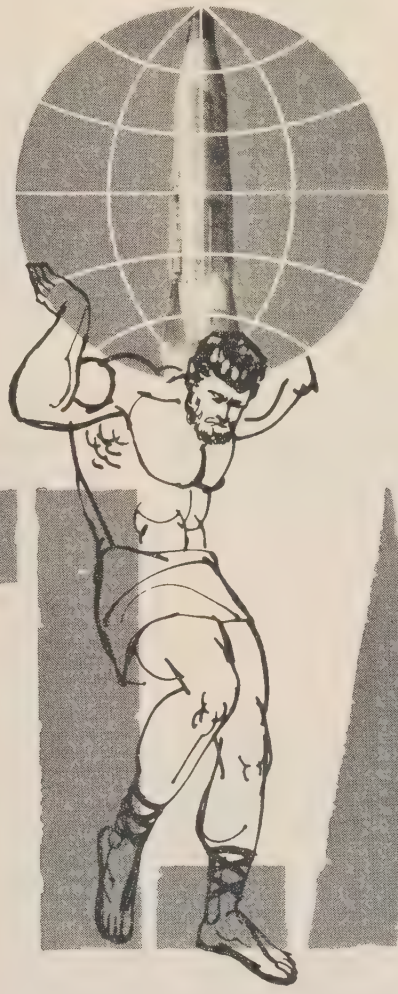

ATLAS

The continuing development of Atlas as well as other USAF missiles and related space probes, has created important positions on STL's technical staff for scientists and engineers with outstanding capabilities in: thermodynamics, aerodynamics, electronics, propulsion systems, structures, physics, computer technology, telemetry, and instrumentation. If you believe you can contribute in these or related fields and disciplines, you are invited to send your resume to:

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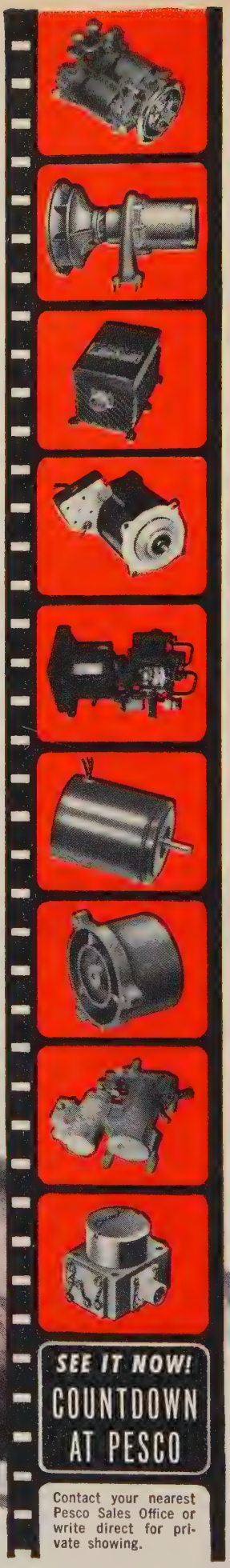

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industry viewpoint

by **Robert M. Loebelson,** Associate Editor

Looking at the transport field

AT A TIME when the debate over the future role of the Military Air Transport Service is at its peak, the newly named vice president and general manager of General Motors' Allison Division is insisting that both MATS and the airlift portion of the Tactical Air Command must be modernized with new equipment.

Says Harold H. Dice, "We must be just as ready to fight small wars as big ones. The only way we can be ready for a small war is to have adequate airlift."

The Allison head sees no logic behind the wrangle over whether the new MATS planes should be turbojet- or turboprop-powered. "We need large turboprops with beaver tails and also turbojets with swing tails. As things stand now, advocates fight for their own preference and both sides end up getting nothing."

Dice, although convinced that MATS and TAC need modernizing, is not prepared to call for a crash program. Modernization, he says, "depends on other military requirements. We may find that the modernization effort will take 10 or 12 years and that we can buy the necessary cargo planes at a reasonable price even if production is only three units a month. But we should get the MATS replacement program going as soon as possible."

Admittedly prejudiced, Dice sees a long range need for large turboprop-powered cargo planes. "The state of the art does not warrant the end of the turboprop, and our T61 proves it." The T61, which is no longer being funded by USAF, was the turboprop engine scheduled for the Lockheed Super Hercules.

The general manager of the Indianapolis engine company also believes turboprops and jets have a great future in VTOL and STOL operations. "The potential of the helicopter is limited. The Service costs of rotary wing vehicles are several times those of fixed wing airplanes. But studies show that jet and turboprop VTOLs will require no more servicing than conventional aircraft." Dice is certain that companies in the VTOL and STOL field are in for "a large piece of business" in the comparatively near future.

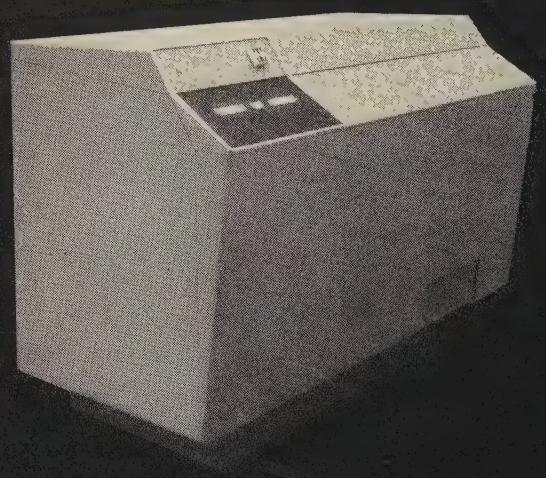
HAROLD H. DICE, vice president and general manager, Allison Div., General Motors Corp.

The Allison official candidly admits there are non-turboprop vehicles that will be highly profitable to their manufacturers. "If I had my choice right now of any aircraft field, I'd want to be in the business of designing and building two new airplanes and the engines to power them," he says. "First, I'd want to be working on a supersonic, medium range transport about the size of the Electra. The plane would feature six-abreast seating and bypass engines and would carry about 80 passengers.

"The other plane would be a large bypass-engine-powered cargo jet featuring a swinging tail. This plane will definitely be ordered by both military and airline users."

Dice does not rule out a Mach 3 jet transport with large engines as a desirable project. "But such a plane can't possibly be developed with airline and engine company funds alone. It must have military sponsorship."

RW-300



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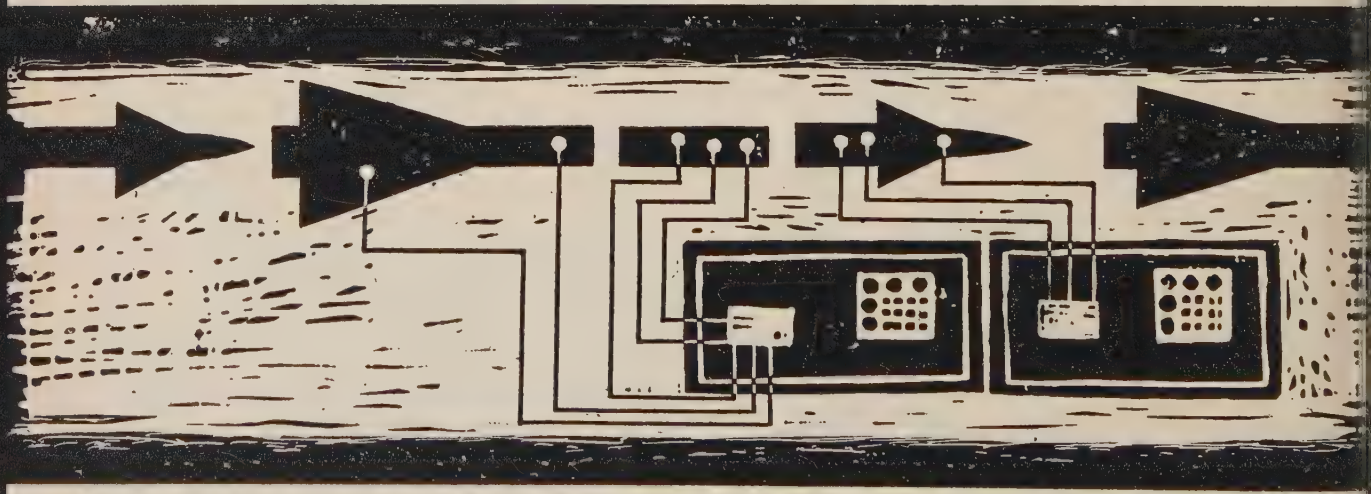

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Tiros satellite is powered by 9200 solar cells

SUCCESSFUL TIROS orbit is a milestone in the development of a worldwide meteorological data system. The satellite is 42 in. in diameter, 19 in. high, weighs 270 lb, and circles earth on an average of once every 1½ hr. Power is supplied by nickel-cadmium batteries charged by 9200 solar cells.

Tiros' two TV cameras differ in coverage and resolution. A side-angled camera is designed to cover a cloud cover area roughly 800 miles on a side from 400 miles altitude; a narrow-angle camera photographs a smaller area within wide-angle camera's view.

The cameras are identical except for their lenses. They have lens speeds of f/1.5 (wide angle) and f/1.8 (narrow angle). Other data: shutter speed, 1.5 millisec; lines per frame, 500; frames per second, ½; video bandwidth, 62.5 kc. A magnetic tape recorder stores up to 32 photos for later transmission when Tiros is out of ground station range.

TIROS remains stable in its orbit at a spin rate of nine rpm or better. When the spin slows down to nine rpm, three pairs of control rockets around the baseplate speed the rotation back to 12 rpm.

The NASA-sponsored program used the Thor-Able as a launch vehicle. The second stage used liquid propellants and was adapted from earlier Vanguard and Thor-Able vehicles. It had six small rockets at the top to spin up the third stage. It weighed about 4000 lb and put out about 7500 lb thrust. The third-stage solid propellant rocket weighed about 500 lb and put out about 3000 lb thrust.

Tiros and its ground station equipment were designed and built by RCA's Astro-Electronic Products Div. ARDC and its contractors, Douglas and Space Technology Labs, were responsible for booster development and mating booster and payload.

Sun's rays are pushing Vanguard I off course

VANGUARD I's ORBIT is being affected by the pressure of the sun's rays. NASA scientists working from orbit data have figured out that streams of photons from the sun are strong enough to push the satellite off course by about one mile a year. This finding came as a big surprise to many scientists who had underestimated the photon energy.

← Write in No. 15 on Reader Service Card

UNDERWATER TESTS of Polaris dummy missiles are being carried out off the Southern California coast. Full-scale models are being launched from submerged and surfaced firing tubes.

The dummy looks just like the Polaris missile. It has the same diameter and overall length and simulates all Polaris launch characteristics (like weight, CG, and pitch moment of inertia). It will be used to check out the submarine launching systems, train sub crews in missile launching, and determine the underwater trajectories of missiles in sea conditions ranging up to hurricane force.

Nuclear payload weighing 120 tons, generating 60,000 kw seen orbiting by '70

NUCLEAR-POWERED electric generating system with a capacity of 60,000 kw could be put into orbit by '70, according to John W. Simpson, vice president in charge of Westinghouse's Atomic Power Division. Simpson told the 1960 American Nuclear Congress meeting in New York City, that by then we should be able to get one kilowatt of power for every four pounds of generator payload. This means we would need a 120-ton payload to generate 60,000 kw. But, Simpson points out, boosters powerful enough to put such weights into orbit are in the cards right now. With the development of nuclear rockets, he says, far heavier payloads will be possible.

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SECOND-STAGE X-15 could put a man in orbit says Thiokol. In a proposal outlined at last month's SAE meeting in New York City, G. R. Cramer and H. A. Barton of the company's Reaction Motors Division proposed that the present X-15 could be modified for an orbital mission by:

- adding auxiliary, droppable fuel tanks;
- using a higher energy propellant (which is already available);
- using it as the upper stage of a 1,000,000-lb-plus thrust booster rocket.

THE HIGHER ENERGY PROPELLANT for the X-15 is a storable combination, Cramer and Barton said, that would "considerably" increase engine thrust. They pointed out that many new propellant combinations, including some that now are in early stages of development (e.g., fluorines and borons), could be used without compromising the X-15 engine's controllability, reliability, and manned-safety rating.

more on next page

POLARIS' temperature and shock monitor controller system was developed by Avien, Woodside, N.Y. According to the company, this system is also being considered for several other programs. It is used to control the shipping container's temperature and to monitor and continuously record shock and temperature levels.

Design concepts proved out on X-1 applied to Atlas, Thor, Saturn, E-1, F-1

EXPERIMENTAL X-1 rocket engine, developed by Rocketdyne, has been a big help in simplifying the design of giant boosters. According to T. F. Dixon, vice president of research and engineering, concepts developed in the X-1 program have been used to improve the Thor and Atlas engines and have been applied to the Saturn H-1 engine, the 400,000-lb thrust E-1 engine, and the single-chamber 1,500,000-lb thrust F-1 engine.

The X-1 is the first of a series of experimental engines developed under BMD's state-of-the-art improvement programs for large liquid propellant rockets. Tests on it started in '58.

NEW CONCEPTS proved out on the X-1 so far include:

- solid propellant gas generator turbine starter to replace the conventional tank system;
- turbine exhaust for roll control instead of a vernier engine system;
- lubrication through the use of a high pressure additive to the fuel system in place of an oil pressure system;
- improved fuel and oxidizer valves for quick engine cutoff.

In tests, says Rocketdyne, the X-1 has been successfully operated at thrusts of over 200,000 lb.

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SYNTHETIC JET OIL was developed that can be stored in tropical areas for five years or longer without deteriorating. Esso Research & Engineering, which developed the synthetic, says it used petroleum raw materials as the starting ingredients. Up to now, it claims, most other synthetic jet lubes have been based on chemicals of vegetable origins.

Esso says its synthetic will meet more stringent specs than it must right now. The Air Force calls for oil to retain its fluidity and lubricity at engine temperatures averaging around 300 deg F and in critical "hot spots" where temperatures are considerably higher. The oil must also be able to perform at —65 deg F.

PYROPHORIC-FUEL afterburning system developed by Sperry and Continental Aviation passed engine qualification endurance testing and is ready for production. It was developed for Continental's J69 engine, which powers the Q-2C Firebee drone.

The control system for the J69 afterburner operates on demand from a ground operator. The remotely controlled drone flies on conventional jet power until more speed or altitude is needed. A ground radio signal then triggers the following sequence: afterburner lines are purged with standard jet fuel to eliminate contamination; the jet engine exhaust nozzle is ejected to create larger area for afterburning; pressure system valves open to start the flow of pyrophoric fuel. When the mission is completed, the control system again purges fuel lines with jet fuel and nitrogen to make the vehicle safe for ground handling.

Snap 8 will weigh 1500 lb, produce 30,000 W with a mercury-driven turbine

SNAP 8 NUCLEAR GENERATOR system, to be built by Aerojet-General for NASA, will cost about $8 million. The reactor is being developed by Atomics International under an AEC contract. The entire generating system should be ready for flight in five years, says NASA.

The initial system should weigh about 1500 lb, including reactor and shielding, and generate 30,000 W. Mercury, vaporized by a closed-loop, liquid-metal reactor circuit, will drive a turbine generator to produce the electric power. After it has passed through the turbine, it will be routed through a series of tubes forming a radiator several hundred square feet in area. Cooling will change the mercury from vapor back to liquid, and then the mercury will be recycled through the closed loop under pressure.

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TWIN GYRO CONTROLLER that can be used instead of reaction jets or inertial wheels to control attitude in space has been developed by Chance Vought's Electronics Division. It consists essentially of two single-axis gyros gimbaled to a common frame torqued about a single axis. Three controllers are needed to control a vehicle's attitude about its three principal axes of roll, pitch, and yaw.

The design's advantage is that the power required for the torquers is insignificant, says Chance Vought. All you need basically is enough to over-

more on page 34

a message to men who are not alone in their thinking . . . Leonardo da Vinci, engineer, scientist, theorist, was the victim of an age when three centuries had to pass before many of his concepts could be regenerated by other men of vision. ☐ Today's quick minds are the fortunate product of an era when methods, materials and machines can be mated to their needs—an age when a spark of inventiveness ignites a fury of progress. ☐ If such a chain reaction of creativity is characteristic of your group, we invite you to discover how Ex-Cell-O can fuse into your operation a reliable source for precision products amply backstopped by research, development and manufacturing facilities, plus the experience required to help you meet the challenge of your own thoughts. ☐ Contact the Ex-Cell-O Representative in your area, or if you wish, call or write direct to our Aircraft Division's central offices, Detroit.

Artist's conception of Leonardo da Vinci's 15th Century spring-driven aerial screw, predecessor of today's helicopter.

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come bearing friction and windage. There is a significant advantage in low weight and power requirements, says Chance Vought, especially when you need continuous or frequent attitude corrections.

GROUND-EFFECT vehicle developed by Curtiss-Wright is being tested by the Army over land and water. Tests over Arctic ice and snow are being planned for this summer.

The Army wants a vehicle to carry a payload of 1000 lb of cargo or four passengers up to 35 mph over unobstructed terrain. Curtiss-Wright's design resembles a car without wheels and is about 21 ft long, eight feet wide, and five feet high.

Draper points out low cost of GSE for inertial guidance, plugs mobile launchers

TAB FOR THE GSE for the inertial guidance system of an ICBM probably comes to about one per cent of the total cost of the GSE for an equivalent radio command guidance system, MIT's Dr. C. Stark Draper estimated for SPACE/AERONAUTICS. His major point in a discussion of airborne and ground equipment was that missile manufacturers should not price themselves out of business as have the aircraft manufacturers with their overly expensive and complex electronic armament and its ground equipment. Draper believes we should place stronger emphasis on mobile ground launching missile launchers and abandon "Maginot" line thinking of hardened fixed sites.

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GSE FOR SPACECRAFT will be a small part of NASA's total budget. In an off-the-cuff estimate before a recent ARS conference, Homer J. Stewart, director of NASA's Office of Program Planning and Evaluation, figured that no more than 5-10 per cent of NASA's budget would go toward modifying existing GSE or building new GSE for space missions.

OUTER SURFACE of the Mercury capsule is of shingle-like construction, using a cobalt-base alloy with integral stiffening, Fred Sanders, project strength engineer at McDonnell, told ARS conference on Structural Design of Space Vehicles at Santa Barbara, Calif. Thermal stresses are lessened, he stated, by using an attachment design giving free movement and bolts of A-286 nickel-base alloy.

Inside a layer of fibrous insulation is the pressure vessel and primary structure. The pressure vessel skins are of commercially pure titanium and stiffened by titanium hat sections. Beaded for local stiffening, they are made of butt-welded segments and seam-welded together. Much of the inner structure, notes Sanders, is made of aluminum.

TIROS SATELLITE's structure takes advantage of proven, reliable manufacturing methods, R. W. Northrop, of RCA, told the ARS meeting. Because of the delicate solar cell installation, it was decided to support cells on a surface strained (in principle) to minimal levels of about 3×10^{-4} in./in., Northrop stated.

Metal "top hat" design was selected so that, in full sunlight, the solar cells could still dump heat through the whole payload and thence to space sink. A monocoque hemisphere design was discarded, since it might have kept the back of one patch of cells from either radiating or conducting readily to the main mass, he stated.

TIROS STRUCTURE uses a flat, circular aluminum baseplate with a central hub, radial beams, outer rim, and enough intercostals to distribute loadings. Eighteen flat-plate solar cell modules are used around the sides of the top hat. Each is supported by vertical risers and from the top.

An aerodynamically supported vehicle for Mars study?

MARTIAN exploration vehicles were described to ARS conference by T. R. Cartaino, of Rand. Design studies were based on minimum payload of 100 lb and a two-man crew (for some missions). With the atmospheric density at Mars' surface about equivalent to the earth's atmosphere at 55,000 ft, Cartaino noted, an aerodynamically supported vehicle is feasible.

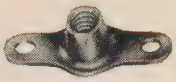
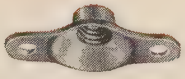
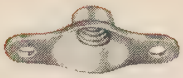
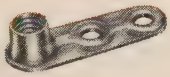
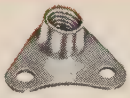
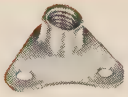
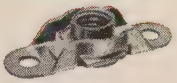
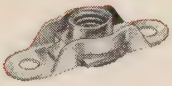
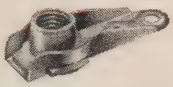
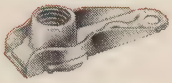
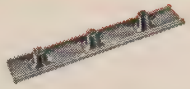
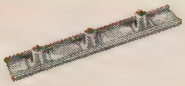
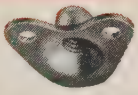
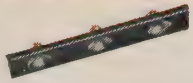
One possibility is a copter. Such a vehicle, said Cartaino, might be a geared-drive, single-main-roto design with a conventional anti-torque tail rotor with a rocket turbine engine. Low disk loading would be needed, because of the low atmospheric density. Body and rotor blades would be inflatable. Landing gear, powerplant, and fuel tanks would be the only metal components. A top cruise speed of 120 knots at 10,000 ft is estimated for the design.

ANOTHER POSSIBLE vehicle, said Cartaino, is a twin-engine, high-wing monoplane with tandem or staggered side-by-side seating. The powerplant would be a rocket driving a prop. An Arado-type high-lift system would be used for STOL opera-

more on page 36

SELECTION CHART

of new counterbored, low height, standard and miniature ESNA/NAS self-locking nuts

Standard—550° F. (Carbon Steels)	Standard—900° F. (A286 Stainless)	Miniatures—550° F. (Carbon Steels)	Miniatures—900° F. (A286 Stainless)
LHTE (NAS 679)	LHTE2860	LH1660	79LH1660 (303 Stainless)
 LHTA51 (NAS 680)	LHTA51-2860	LHTA51M (NAS 697)	LHTA51M2860
 LHTA58 (NAS 681) – 100° Ctsk	 LHTA58-2860 100° Ctsk	LHTA575M (NAS 1067)	LHTA575M2860
 LHTA57 (NAS 682)	LHTA57-2860	LHTA57M (NAS 696)	LHTA57M2860
 LHTA55 (NAS 684)	 LHTA55-2860	LHTA55M (NAS 698)	LHTA55M2860
 LHTA521 (NAS 686)	 LHTA521-2860	LHTA521M (NAS 1068)	LHTA3300
 LHTA517 (NAS 687)	 LHTA517-2860	LHTA3575	
 LHTG51 (NAS 688-92)	 LHTG51-2860		
LHTA54 (NAS 683) 100° Ctsk			
 LHTA35 (NAS 685) 100° Ctsk			
 LHTG55 (NAS 693-5) 100° Ctsk			

To meet the requirements of the aircraft, missile and avionic industries for lighter-weight, reduced-dimension fasteners for elevated temperature service, ESNA has designed and is *currently producing* all of these new self-locking nuts. Every part conforms to NAS specifications and the entire line has full Military Services approval.

This is just a part of the *complete line* of self-locking Elastic Stop® nuts which only ESNA offers as standard parts, including AN 362, 363, 364, 365 and 366 types; also special designs such as high tensile, barrel and self-aligning fasteners, all types of straight and radius gang channels and very high temperature all-metal slotted beam designs for use on jet engine applications at temperatures in a range of 1200°F.

For free copy of ESNA/NAS conversion table containing both NAS drawings and ESNA equivalents with full details, write Dept. S12-550 Elastic Stop Nut Corporation of America, 2330 Vauxhall Road, Union, N. J.

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ELASTIC STOP NUT CORPORATION OF AMERICA

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tion. Wing loading would be 15 psf; design cruise speed would be about 180 knots. Because of low atmospheric density, the prop blade area would be large compared to that of conventional aircraft.

SUPER TALOS and Super Tartar air defense missiles, being developed by Johns Hopkins' Applied Physics Lab, were redesignated "long range Typhon" and "medium range Typhon." They will be used against enemy aircraft and missiles. Westinghouse received a $38.5 million Navy order to build a prototype of the radar portion of the Typhon systems.

Army missile planning calls for successors to Lacrosse, Honest and Little Johns

ARMY FEASIBILITY STUDIES on Missile A, a later-generation, copter-transportable missile to support infantry battle groups, have been completed. Missiles A and B will eventually replace Lacrosse and Honest and Little John. Missile C —a probable Sergeant successor—will be used to support Army corps. Missile D's function will be handled by the Martin Pershing.

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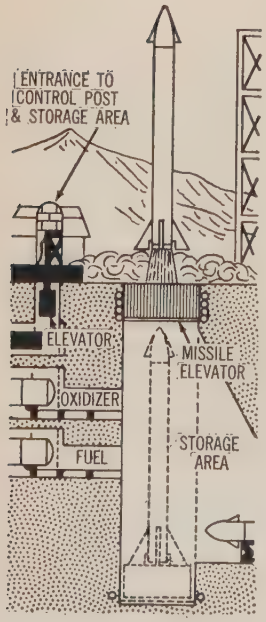
SUCCESSFUL CERAMIC brazing jig fabrication was reported by Gladding, McBean & Co., of Los Angeles. A special ceramic material with low thermal conductivity is used, it's stated, so that tubes can be thoroughly brazed together without the brazing materials becoming brittle on cooling. The ceramic also is said to resist wetting by the braze material.

The jig is suitable for furnace and torch burning. The original manufacturing costs are small, it's reported, and the jig can be re-used many times.



RUSSIAN ICBM launch site was shown in Soviet publication (see *Diagram*). Hardened facilities are provided for liquid propellant servicing, multi-missile magazine, and erecting mechanism. The exposed above-ground tower, interestingly enough, indicates a servicing requirement after the missile is raised for launching.

INFLATED STRUCTURES for orbital flight and re-entry were proposed to ARS by F. B. Sandgren and J. T. Harris, of Goodyear Aircraft. Such designs, they noted, can be completely assembled on the ground, packaged to a minimum side, installed in the cavities of a launch vehicle's final stage, and automatically deployed into space at the desired position. Inflated structures, they said, can now be made from woven flexible materials—like fiberglass, cotton-neoprene, nylon-neoprene, Fortisan-neoprene, and Dacron-neoprene—to any desired shape.

Assuming the final stage of a missile like Saturn as the basis for a space station, the Goodyear engineers report the available space (10 ft in length by 40 ft in diameter) would be suitable for a crew of four. An expendable structure with a packaged-to-inflated volume ratio of 300:1, they say, would provide room for 22 men under the same conditions.

3200-cycle turbine output is converted to 60 or 400 cycles

NEW SMALL GAS TURBINE using silicon-controlled rectifiers and generating 3200-cycle electricity was reported by Garrett's AiResearch Mfg. Div. of Phoenix, Ariz. The high frequency output is statically converted to either 60 to 400 cycles to free the turbine from the restrictions of gearing high turbine rpm down to low reciprocating engine speeds.

Under development is a 60-cycle, 100-kw turbine-driven generator driving a high speed, shaft-power generator mounted directly on the turbine. The complete set, says AiResearch, will weigh only 800 lb.

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RADIATION-RESISTANT camera designed for long exposures to nuclear environments was produced by ITT's Industrial Products Div., San Fernando, Calif. It can be used for close inspection of nuclear reactors when the radiation is too intense for test cell observation windows and periscopes won't do. Present closed-circuit cameras, according to ITT, are knocked out after 10-30 minutes by radiation damage. The new, radiation-resistant camera's special construction materials include aluminum, silicon, magnesium, titanium, and zirconium. Ceramic electronic components are used in the control circuits.

MARINE CORPS indicated a requirement for an assault version of the Sikorsky HSS-2 anti-sub copter. The HR3S, powered by two GE T58s, will carry 22 combat-equipped Marines at speeds up to 135 knots.

3M Materials Memo

News of materiel for the aerospace industry—from the 27,000 products of the 3M Company

■ FIRESIDE FASHIONS

You might not want to wear it in the Easter Parade, but a suit made of "Scotch-Shield" Heat-Reflective Fabric is in good taste for strolling through infernos. Such suits have been really hot items among fire fighters, both in the military and civilian life for some time now. More recently, in the form of sleeves, they've been bouncing heat off of expensive umbilical cables on the launch pads of some of our larger missile systems. They're a natural, too, as protective shrouds and bags for controls or instrumentation components — on the pad, or in the missile itself.

Resistance of these fabrics to radiant heating is well illustrated by this test performed in our Reflective Products Laboratory. A Globar heating element radiating at 2600° F. was placed at the one focus of an elliptical reflector. The sample of "Scotch-Shield" fabric was placed at the other focus. Even after 2 or 3 minutes of exposure, no burn-through took place. Under identical conditions, even flameproofed conventional fabrics disintegrate in seconds. An even more vivid test took place when an imaginative laboratory technician entered a blazing furnace carrying a raw T-bone steak on a platter. When he emerged minutes later, the sizzling steak was done to a turn.

The key to this phenomenal performance lies in the micro-thin aluminum film securely deposited on the surface of the light weight flame proof cloth backing. This finish, reflecting more than 90% of all radiant energy, unlike heavier aluminum foil won't crack or peel away from the backing. Furthermore, it doesn't detract from the original drape of the fabric or add noticeable weight. Those fabric backings available as standard products are the cotton, glass, and asbestos combination, the herringbone asbestos, and flame proofed rayon. If these don't suit your particular needs, special base fabrics are available on minimum yardage basis. If "Scotch-Shield" kindles your imagination, why not check with your REFLECTIVE PRODUCTS representative, or fill in the coupon below?

■ YOUR BIRD CARRYING A TORCH?

It might be doing just that, if you're still using conventional encapsulating resins on its hot little electronic innards. Of course, finding a truly flame proof resin system hasn't been an easy task. That is, not until "Scotchcast" XR-5019 entered the scene. This new two-part flexible epoxy resin system is so flame proof that it doesn't burn, even when given all sorts of encouragement. For example, in the Manson flammability tester—one that's really a scorcher—XR-5019 beat the standards of NEMA for non-flammable resins by a substantial margin. In this test, where the goal is to get the lowest possible number, values of 0.55 to 0.80 were achieved by XR-5019. These figures can be compared to a value of 6.2 for a conventional casting resin, which, incidentally, also passes the flammability requirements of Mil I-16923C. One manufacturer enthusiastically reports that XR-5019 insulated transformers have met the flammability requirements of even Mil T-27A without a waiver, which is something of a "first."

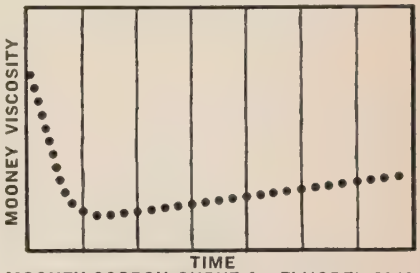
But this versatile resin system doesn't put all its eggs in one basket. In a thermal shock test developed by 3M, the resin cured around a ¼" metal insert is recycled between 130° and −55°. XR-5019 was cycled for ten times, with no failures. And its virtues don't end there. It features low impregnating viscosity and high adhesion to most metals. Its pot life of 3 to 4 days after mixing is nothing to overlook, either. Needless to say, these advantages are not offered at the sacrifice of electrical properties. Why not contact your local ELECTRICAL PRODUCTS representative, or check the box below for additional information?

■ SOME GUM!

A real aristocrat among synthetic elastomers is our CHEMICAL DIVISION'S new "Fluorel" 2141 Brand Elastomer. This fully saturated polymer is fluorinated to the hilt—containing greater than 60% fluorine by weight. Once you've been exposed to "Fluorel's" remarkable stability you'll realize that the fluorine is not along just for the ride.

Chemical stability is just one area in which it takes the blue ribbon. It resists almost all fuels, lubricants, and hydraulic fluids currently being used or developed for rocket and missile systems, even the high energy fuels of the boron type. It takes hot oils, many organic solvents, as well as strong inorganic acids and bases in its stride. Nor does it have to be pampered, as far as outdoor weathering is concerned.

High temperature is no enemy to "Fluorel," either. It performs under continuous long-time service at 400° F. without marked degradation. Under some conditions for reduced periods of exposure, temperatures above 600° F. can be tolerated. Then of course there's the fringe benefit of its excellent resistance to compression set, which is a handy property to have around, if you're concerned with seals or closures.



MOONEY SCORCH CURVE for FLUOREL 2141

Offering properties like these, you might expect that "Fluorel" would be a real prima donna when it comes to compounding—tain't so! It's easily processed on standard rubber compounding equipment with a Mooney Scorch rating ideal for the rubber processor—can be molded, extruded, and adhered to metals. It's natural for application to O-rings, gaskets, tubing, expellant bladders, fuel cells, and countless other demanding areas.

For a complete brochure on properties and handling of "Fluorel," contact your Chemical Division representative or check the coupon below.

And if you have questions on any of the items mentioned here, or would like to know what else 3M makes—or could make—for your needs, mail coupon.

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Engineering notes from the **SM/I REPORTER**

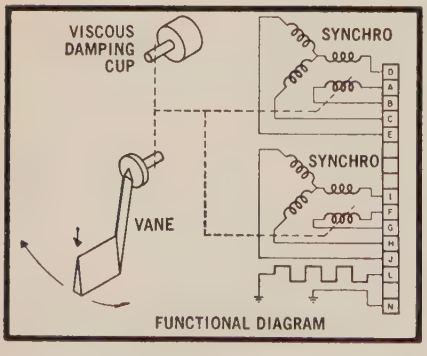
BY STANLEY M. INGERSOLL, *Capabilities Engineer*

Report No. 5
TR 722-2 Angle of Attack Transmitter

Precision built and self-powered, the TR 722-2 provides an electrical output proportional to the direction of local airflow surrounding an aircraft. It may be used to transmit local angle of attack or yaw, and its output signal can be applied directly to a visual indicator. The TR 722-2 is ideal for use on all types of military jet aircraft because of its accuracy, inherent stability, compact packaging and rugged design. The vane air foil used is drag stabilized and has passed rigid military qualification programs. The TR 722-2 has been qualified by Wright Air Development Center and is listed on Qualified Parts Lists under MS24378. The unit meets or exceeds MIL-T-25627 and amendments.

Typical Performance Specifications

Electrical Output	Two Synchro Transmitters
Electrical Angle	135°
Mechanical Angle	50°
Sensitivity:	
90 to 125 knots	0.2°
125 knots to Mach 4.37	0.1°
Power Requirements	115V at 400 Cycles
	26V at 400 Cycles
Heater	115V
135 Watts Max. at	30°C.
Electrical Output Error	±0.2°
Temperature Range	−54°C. to +93°C.
Damping	0.75 Critical at 110 knots
Weight	1.8 lbs. max.



TR 722-2 Angle of Attack Transmitter

For more information and complete operating specifications, write or wire SM/I today. Address your inquiry to Stanley M. Ingersoll, Capabilities Engineer.

SM/I SERVOMECHANISMS/INC.
Los Angeles Division
12500 Aviation Boulevard
Hawthorne, California

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calendar

May 9-11—Symposium of the Institute of Radio Engineers' Professional Group on Microwave Theory and Techniques, Hotel del Coronado, San Diego, Calif.

May 9-11—Power Instrumentation Symposium, Instrument Society of America, San Francisco State College, San Francisco, Calif.

May 9-12 — Instrument-Automation Conference & Exhibit. Civic Auditorium & Brooks Hall, San Francisco, Calif.

May 9-12—Meeting & Astronautical Exposition, American Rocket Society, Ambassador Hotel, Los Angeles, Calif.

May 9-13—Southwestern Metal Congress & Exposition, American Society for Metals, Sheraton Dallas Hotel & State Fair Park, Dallas, Tex.

May 9-13—Society of Photographic Scientists & Engineer Conference, Miramar Hotel, Los Angeles, Calif.

May 10-12—Electronic Components Conference, IRE Professional Group on Components Parts; American Institute of Electrical Engineers; Electronic Industries Assn.; Western Electronic Manufacturers Assn., Willard Hotel, Washington, D. C.

May 11-14—The Fluid Controls Institute Spring Meeting, The Greenbrier, White Sulphur Springs, West Virginia.

May 17-19—Power Sources Conference, Power Sources Div., U. S. Army Signal R&D Lab, by invitation only, Power Sources Division, USASRDL, Ft. Monmouth, N. J., Shelbourne Hotel, Atlantic City, N. J.

May 17-19—American Society of Mechanical Engineers, Production Engineering Conference, Schroeder Hotel, Milwaukee, Wis.

May 18-20—National Meeting, Society for Experimental Stress Analysis, Stress Analysis of Propulsion Systems — Theme, Hotel Severin, Indianapolis, Ind.

May 23-25—National Telemetering Conference, AIEE, ISA, ARS, Hotel Miramar, Santa Monica, Calif.

May 23-25 — German Society for Rocket Engineering & Space Flight Research Meeting, Heidelberg, West Germany.

May 23-26—ASME Design Engineering Conference & Show, Statler Hilton, N. Y.

May 24-27—Aircraft Electrical Power Systems Conference, Sundstrand Aviation, Faust Hotel, Rockford, Ill.

May 24-26—American Society for Quality Control Convention, San Francisco, Calif.

May 25-27 — National Specialists meeting, Guidance of Aerospace Vehicles, Institute of the Aeronautical Sciences, Boston, Mass.

May 26-27 — "Psychophysiological Aspects of Space Flight" Symposium, School of Aviation Medicine, USAF Aero-Space Medical Center (ATC), and arranged by Southeast Research Institute, unclassified, but by invitation, Hilton Hotel, San Antonio, Tex.

June 13-14—International Powder Metallurgy Conference, Institute of Metals, Div., The Metallurgical Society, American Institute of Mining, Metallurgical & Petroleum Engineers, Hotel Biltmore, N. Y.

June 20-23—Avionics Panel, Theme —Radio Wave Absorption, Advisory Group for Aeronautical Research & Development-NATO, Athens, Greece.

Aug. 15-20—11th Annual Congress, International Astronautical Federation, Royal Institute of Technology, Stockholm, Sweden.

PICTURE CREDITS: Cover—S/A-Pursell; pp. 40-41—S/A; pp. 42-45—S A; 46-51—Battelle Memorial Inst., Stanford Research Inst.; pp. 52-54—Boeing Airplane; pp. 59-65—Reeves Instrument; pp. 75-90—S/A, North American Aviation; pp. 93-96—NBS; pp. 101-112—DOD; pp. 137-144—NBS; pp. 162-165—Space Technology Labs., S/A.

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Pacific's

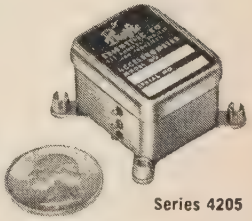
PRECISION LINEAR ACCELEROMETERS are rugged and right!

Pacific's family of accelerometers are designed, developed and tested to meet almost any acceleration measurement requirement. Their custom design provides excellent reliability and accuracy for many critical applications – combining features of lightness with high precision characteristics.

To save you time and money, many of Pacific's accelerometers can be incorporated into your own designs at an early stage.

Each of the basic models illustrated at the right is representative of a series of similar units which vary only in output characteristics. They are available and were developed to satisfy a special requirement but can now be considered as standard production items...completely tooled, qualified, proved in actual use ...ready for immediate order.

For complete information on a Pacific accelerometer designed to your own requirements ... or on a modification of these units, WRITE TODAY. The engineering skill and creative ability of Pacific Scientific are at your service.



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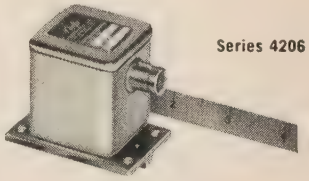

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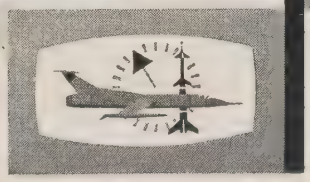

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Basic research balance sheet:

not enough money not enough men

This is the second article in a series analyzing the country's requirements for basic research and showing how they are being met. As a matter of fact, they aren't being met, this article points out.

by **Robert M. Loebelson**
Associate Editor

"THE SECURITY OF THE U.S. depends . . . upon the rapid extension of scientific knowledge. So important, in fact, has this extension become to our country that it may reasonably be said to be a major factor in national survival."

Sounds familiar, doesn't it? Yet these words were written back in 1947, in a report by his Scientific Advisory Board to President Truman.

In the 13 years since 1947, there has been no lack of voices calling for a strong U.S. basic research program. But the actual national policies on basic research have been something else again—they've been rather a see-saw affair.

At one extreme is former Defense Secretary Charles E. Wilson's 1955 statement that DOD was not interested in finding out why grass is green. Against this you can put President Eisenhower's budget message this year, which requested more than $600 million "to provide a strong foundation of fundamental scientific knowledge for the nation's future advancement."

And what has been the result of the see-saw so far? Today, the Defense Department and the National Science Foundation (NSF) agree that fund shortages are keeping us from starting new basic research studies.

In fiscal 1957, for example, DOD's Coordinating Committee on Science rejected 804 study proposals in fields ranging from astrophysics through mathematics to oceanography even though they were officially considered "meritorious". These programs would have cost close to $45 million and would have boosted DOD's 1958 budget of $65.6 million for basic research by 70 per cent.

Another set of statistics with the same conclusion is provided by NSF. For the five years ending with fiscal 1957, NSF was asked to provide $140.2 million to support proposals it had judged to be "meritorious". But during these five years, only $38.8 million in research grants was awarded by NSF. The other $101.4 million worth of meritorious proposals went unfunded.

One of the most interesting aspects of the basic research problem is that, while virtually everyone agrees that the government should fund most basic studies, industry has been much more aggressive in this regard than the government. This is proved by an NSF study run on research from 1947 and 1957 in five technically based industries: chemicals, petroleum, communications, electronics, pharmaceuticals, and materials. Data from the two most successful companies in each industry showed that by 1957 all these firms were devoting 10-20 per cent of their own R&D expenditures to basic research. The average allocation was 16 per cent.

The 14 top companies in these five industries tripled their overall R&D expenditures between 1947 and 1957 and stepped up their basic research spending by 350 per cent.

Rise in funds offset by inflation

The military services now allocate 6-8 per cent of their R&D money to basic research. The increase in their basic research spending from 1947 to 1957 came to 50 per cent. This increase was pretty completely offset by the inflation—the cost of maintaining and paying a scientist also went up by about 50 per cent.

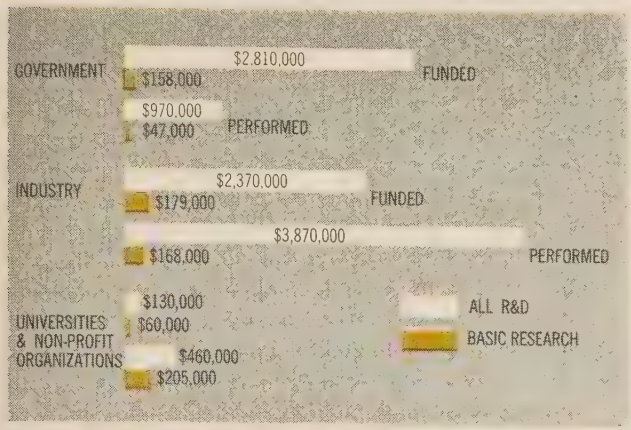


FIGURE 1: Distribution of research funding and work as shown in a National Science Foundation survey covering fiscal 1954 (left). The three major groups shown here accounted for 98.5 per cent of all R&D spending and 96.8 per cent of all basic research spending.

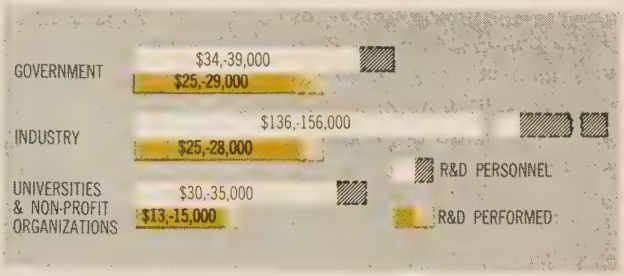


FIGURE 2: Personnel data for R&D from the 1954 NSF study.

Money alone, of course, isn't enough for basic research. Manpower is at least as important—and here the outlook again is bleak. Our manpower for basic research is small, even worse, it is shrinking while the need for research is growing.

A recent study by Arthur D. Little, Inc. of Cambridge, Mass., shows the U.S. now has about 27,000 basic research scientists. However, only about 15,000 of these are active in research to the extent of publishing on work in their specialties.

Some of the facts turned up by the Little study are:

- Some 9000 doctorates are awarded by American universities each year in both the sciences and the arts. However, only one out of every five Ph.D.'s in science has the creative skill and the urge to go into basic research.
- Basic and applied R&D activities are expanding by 10 per cent each year, but the number of scientists available for this research is increasing by only five per cent annually.
- The ratio between the various doctorates has remained virtually unchanged since 1932. Now as then, 30 per cent of the doctorates are in the physical sciences, 20 per cent in the life sciences, and 50 per cent in other fields.

Industry does bulk of R&D work

Now what about the basic research that is being done: Who is doing it, and who is paying for it?

An NFS survey covering a 12-month period in the years 1953-54 shows that industry accounted for the bulk of the nation's R&D effort, including civilian and military projects financed by DOD and other government agencies. However, the eight per cent of R&D work that is labeled "basic" is predominantly done by universities and other non-profit organizations (*Fig. 1*). On the other hand, industry and government shared almost equally in the support of R&D, and the non-profit institutions clearly relied on them to finance many of the projects they carried on.

NSF's survey also revealed that government labs accounted for 18 per cent of the nation's R&D work and 17 per cent of all R&D personnel. For industry, the figures were 72 per cent for R&D and 68 per cent for personnel; for non-profit institutions, nine per cent for R&D and 15 per cent for personnel.

Government and industry R&D cost $25-$30,000 per man researcher, but for the non-profit institutions this figure is only about half as large (*Fig. 2*). Of course there are reasons why R&D at universities and similar institutions is cheaper per man. For one thing, universities tend to favor research projects that do not involve large capital expenditures. They also have inexpensive help readily available in the form of students, pay comparatively low salaries and charge low overhead fees on contracts.

Everyone who has to do with basic research agrees that government, industry, and non-profit institutions should and can do more basic research. The $600 million cited for basic research by the President for 1961 looks like small potatoes compared with the $3.9 billion allocated for farm price supports, the soil bank, the sale of surplus farm products, and the like. Many supporters of basic research—in and out of the aerospace industry—are certain that, if the U.S. can spend as much as it does on fram programs each year, it can find the dollars to make sure that admittedly "meritorious" research projects are funded in time.

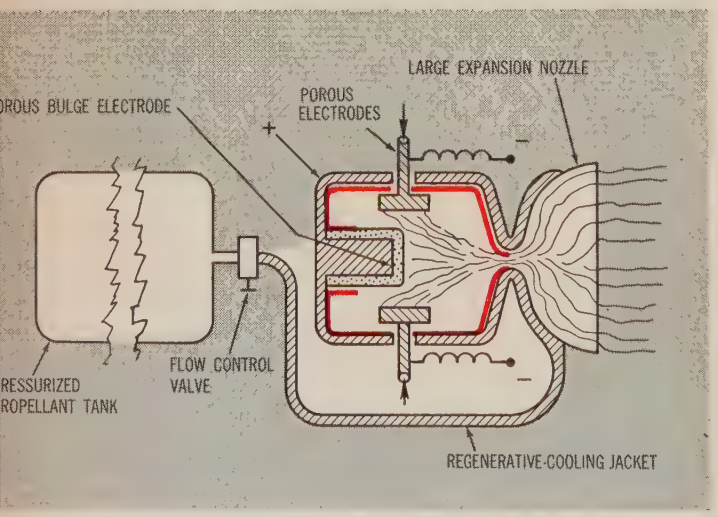
"The danger is not in starting too many R&D projects—the real danger is in not starting enough," says R. R. Clark, general manager of Chance Vought's Astronautics Division. "R&D spending is the seed corn. What is needed is the courage, vision, and determination . . . to weed out the less promising plants after they have sprouted and before they grow too far from the ground—regardless of the pressures to let the weeds grow and sap strength from the good plants."—End

Arc-jet and photon rockets:

propulsion for near and far future

This is the last article in a series covering the various forms of electric rocket propulsion. Earlier articles reported on the state of the art in plasma and ion rockets.

by Kurt R. Stehling
Contributing Technical Editor



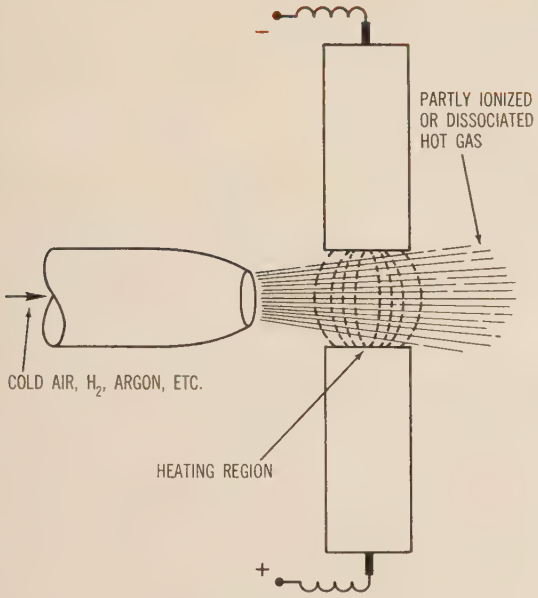
VERY SIMPLIFIED schematic of an arc-jet rocket. The propellant might be liquid H_2, argon, etc. The ceramic lining (color) insulates the negative electrodes from the positive one. It might be made of Niafrax, boron nitride, etc.

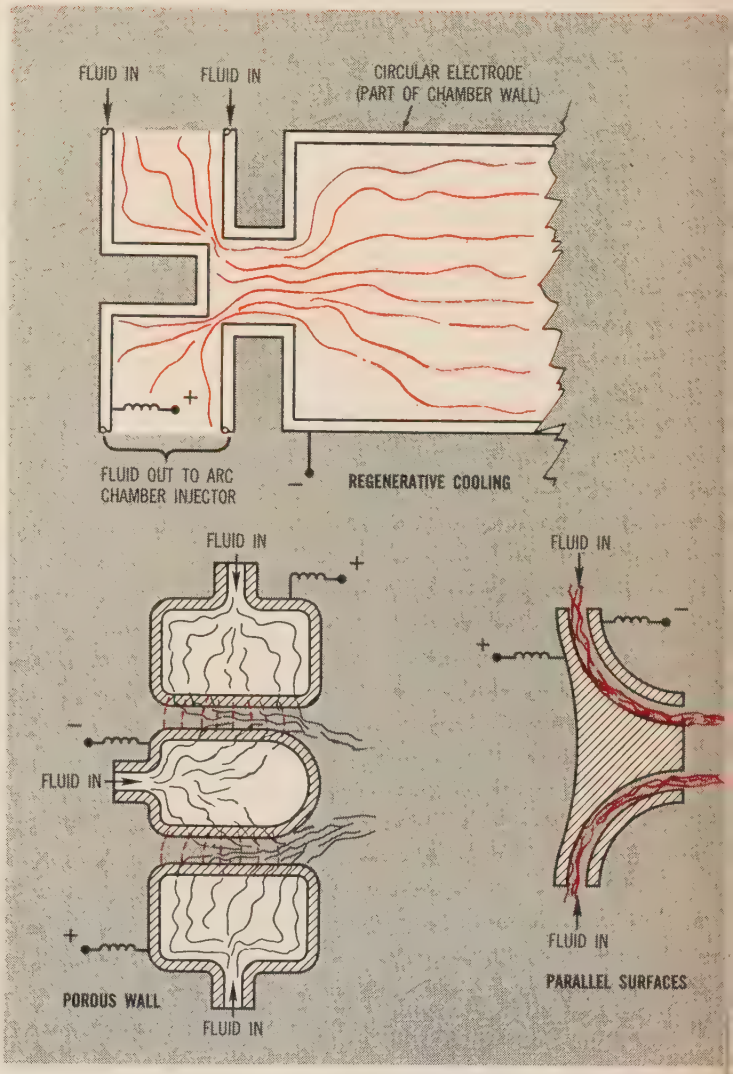
IN AN ARC-JET rocket, a gaseous working fluid flows through an electric arc, in which it is heated to a high temperature, and is exhausted, after passing through a stagnation chamber, through a regular expansion nozzle. The interval in the stagnation, or settling, chamber is used to remove non-homogeneieties from the working fluid.

The electric arc is produced by separated metal electrodes. Normally such electrodes would not arc—even when they had first come into contact—unless enormous currents and very high voltages were applied. An arc is "struck", however, when a jet of gas or even water is blasted through between the electrodes. The fluid between the electrodes quickly heats up and ionizes, and becomes conductive. As a result, electric power is dissipated and sharply raises the temperature of the working fluid.

Though basically an electric propulsion system, the arc-jet rocket resembles the chemical rocket in two essentials:

- The working fluid acquires *thermal* energy (de-





BASIC PHENOMENON of arc-jet propulsion (above) is the arc "struck" when a jet of gas (or even water) is blasted through between two electrodes. The rapidly heating and ionizing fluid becomes conductive. Because of the electric power dissipated in the process, the temperature rises sharply. Right: Three types of arc electrode designs to meet the requirements of cooling and ablation protection.

rived from Joule, or resistance, heating as it is pumped through the arc).

• The acceleration process is *thermodynamic*, rather than magnetic (as in the plasma rocket) or electrostatic (as in the ion rocket).

The designation "plasma arc-jet", which is sometimes used, is clearly a misnomer. To begin with, at no point in an arc-jet does more than about 10 per cent of the fluid consists of electrically charged particles—yet a plasma is defined as a fluid in which such particles make up a large proportion of the total mass (more than 50 per cent, say).

Its similarities to the chemical rocket give the arc-jet rocket several advantages over other electric propulsion systems:

• Since the working fluid is thermally heated and expanded, no major magnetic or electric equipment in the engine proper is needed beyond a pair of electrodes, and the design is that much simpler.

• Partly because the working fluid is accelerated thermodynamically, rather high thrust levels are reached —higher ones, at least, than are possible with either a plasma or an ion rocket.

The thrust of an arc-jet rocket depends mainly on the power dissipated across the arc and on the mass flow of the working fluid. Today, the limiting factor is still the power that can be dissipated, which has kept the heating process at an efficiency of only some 50-60 per cent.

Since thrust is achieved by the isentropic expansion of heated gas in a nozzle, some thrust control is provided "automatically": if the expansion ratio of the nozzle is changed, the thrust is changed, too.

When the working fluid is heated to more than 6000 deg F, its molecules and atoms begin to break up and dissociation and ionization take place. If this process is

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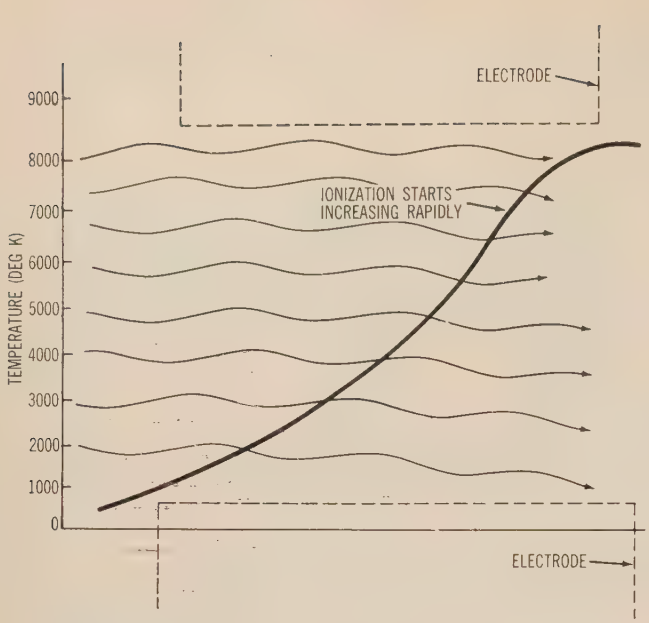

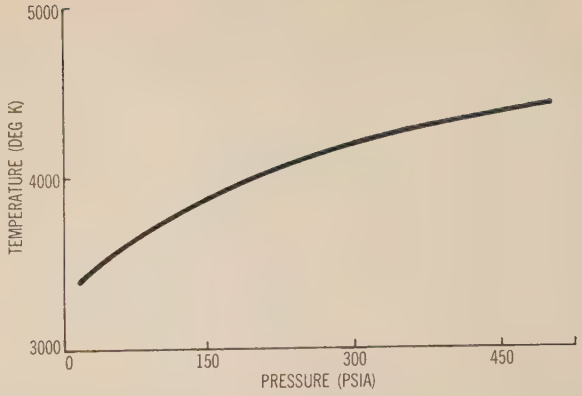

APPROXIMATE temperature rise of argon at 500 psia as it flows between two simple electrodes (left). The transit time is about 10 millisec, the current density is assumed to be about 1000 amp/sq in. Right: Pressure vs temperature in an arc for air. The values for this curve are very rough and assume an efficiency of 20 per cent for the conversion of electric power to kinetic heat energy as well as a fixed value of arc power.

extensive, some of the energy normally used for the thermal heating of the working fluid is diverted. The dissociation and ionization energies acquired in the arc are lost for propulsive purposes, since they do not reappear as kinetic energy in the exhaust stream. The so-called "frozen flow" of dissociated or ionized gas also occurs in chemical rockets, but only to a lesser degree, since the stagnation temperatures and ionization and dissociation rates of chemical rockets are lower.

Energy loss can be made up again

The interesting point is that dissociation and ionization energies are not lost irretrievably—if the molecules and atoms that have broken up recombine before they leave the nozzle, heat is released and kinetic energy is regained. The rocket designer tries to favor such recombination by lengthening his nozzle and carefully watching its expansion ratio. Unfortunately, he doesn't gain much control over the recombination process in this way, and so far we don't know of any technique that might further recombination in an arc-jet rocket. Nor, for that matter, do we know how much energy is lost through frozen flow in this type of engine.

The question of recombination affects the choice of a working fluid. Among the fluids for which strong arguments can be made are:

- *helium*, which has a high efficiency at specific impulses below 1600 seconds, being a monatomic gas;
- *lithium* vapor, which has a high efficiency at specific impulses from 1600 to 2500 seconds;
- *hydrogen*, which has an extremely low molecular weight, a good specific heat, and good coolant characteristics.

Hydrogen now looks most promising for arc-jet rockets, even though it has several clear drawbacks. Since it normally occurs in its molecular form, dissociation may lower its efficiency. There is some evidence, however, that hydrogen to a degree recombines in a nozzle; if this proves true, its efficiency should exceed that of helium.

Another problem with hydrogen is storage. Liquid hydrogen (which would have to be used if any decent sort of specific impulse is to be achieved) is hard to store even under normal conditions, not to speak of those of space flight. Nevertheless there is hope that, within the next 2-3 years, we will come up with the necessary radiation shields, multi-jacketed pressure vessels, and insulations and be able to store liquid hydrogen in space for days and even months without too much boil-off.

Among the design problems of the arc-jet rocket, the foremost has to do with heat—not a surprising state of affairs when you are dealing with a system in which temperatures of 5000-10,000 deg F are developed at gas pressures exceeding one atmosphere. In chemical rockets, whose heat transfer rates may run as high as several btu/sq in./sec, one of the propellants is generally used as a regenerative coolant. In an arc-jet rocket, the propellant flow rate is much lower than in a chemical rocket. Regenerative cooling of the arc chamber (in which most of the heat is developed) is very difficult, therefore, unless very high pressures and very narrow cooling passages can be used.

Radiators are suspended from craft

Another cooling method is to use large radiators that are suspended from the spacecraft and from which heat carried from the arc chamber by a recycling fluid would be radiated into space. Such radiators naturally would work only if protected from solar radiation. Moreover, they would require such large surfaces that their bulk might cause major design problems. However, as regenerative cooling might be ruled out by the low propellant flow rate, some form of radiation may well prove to be the only solution.

As the gases expand in the nozzle of an arc-jet rocket, there may be further heat release and there will, of course, be heat transfer. However, these effects would be much milder than those in the arc chamber. Ablative or ceramic-lined walls might perhaps improve the heat

resistance of the nozzle; indeed, they might prove valuable for the arc chamber, too.

The electrodes also pose a cooling problem—they can become so hot that some of their material is vaporized. The efficiencies of both the electrodes and the working fluid then are reduced, since the electrode gap is increased and dense electrode material enters the gas flow.

The most promising electrode cooling scheme seems to be to use porous electrodes, made of metallo-ceramic or metallic material, and bleed the working fluid through them. With this form of gas film cooling, you achieve at the same time an arc and gas boundary layers that prevent excessive heat transfer. (Of course, these layers will not stop the radiative heat transfer from the hot mass of gas in the arc chamber.)

Large electrodes cut down heat transfer

The designer may also choose to rely on very large electrode areas to minimize the heat transfer per unit area (see *Diagram*). Naturally, such an arrangement makes for extra weight and bulk.

The electrodes are also exposed to ablation through the physical action of the working fluid as it flows by or through excessive ionization or combination with the working fluid. Porous electrodes might overcome this danger, too, by virtue of the cooling and cushioning effect of their gas film. Very large electrodes also would suffer little ablation.

Other design problems, on which more R&D work is needed, are:

- Pressures of more than one atmosphere yield higher thrusts; however, they also raise the requirements for propellant tank pressurization, gas flow, erosion protection of electrodes and arc chamber, and nozzle size and weight.
- By a combination of power level changes and gas flow throttling, thrust control could be achieved—once the relationships between the factors involved in this process are better understood.
- At very high temperatures, certain magnetic effects occur in the gas (which may largely be plasma in this case). These effects may lead to excessive interaction of magnetic fields. On the other hand, it might prove possible to use these magnetic fields for containing hot gas in the arc chamber and the settling region in an arc-jet rocket that comes close to the plasma engine.

Operational engine in three years

Because of its simplicity, the thermal arc-jet rocket may be the first electric propulsion device to be used to produce thrusts of more than a few pounds. With hydrogen as the working fluid and arcs at levels above 50 kw, it should reach specific impulses of 1000-5000 seconds. These would qualify it for certain lunar missions, orbital maneuvering, and perhaps some flights to the nearer planets. The first arc-jet rockets suitable for spacecraft weighing several tons should become operational within the next three years.

As for all forms of electric propulsion, a light power supply is essential for the arc-jet rocket. For flights to the moon and beyond, this power supply probably will have to take the form of a radioisotope or nuclear-reactor device.

At the other end of the electric-propulsion spectrum from the arc-jet rocket is the photon rocket, whose thrust is produced by the pressure of radiation—which may be visible light or any electromagnetic radiation. Actually, photon propulsion is in a class by itself, since it involves energies and thrust levels that get us into new orders of magnitude.

Theoretically, a photon rocket can achieve a specific impulse approaching 25,-30,000,000 seconds—if we manage to convert mass entirely into energy. To produce a light beam (which is what the "jet" of a photon rocket really is) that can provide a pound of thrust by its irradiation pressure, a power input of about 1500 Mw would be needed, or at least a thousand times as much power as is required for a system like the arc-jet rocket.

The alternative to the generation of such power inputs would be to use the radiation pressure of sunlight or to convert solar energy directly into light energy. But for these schemes, fantastically large reflectors would be needed: To collect enough solar energy to produce a pound of thrust, a reflector would have to have an area of 7,-10,000,000 sq ft, or a diameter of ½-⅔ miles.

For the foreseeable future, we just don't have to worry about photon propulsion. Some day, when we're ready for *interstellar* travel, designers might come back to the photon rocket as a practical propulsion device. By that time, we conceivably might have nuclear fusion "lamps" strong enough to produce the light beams for these rockets.—End

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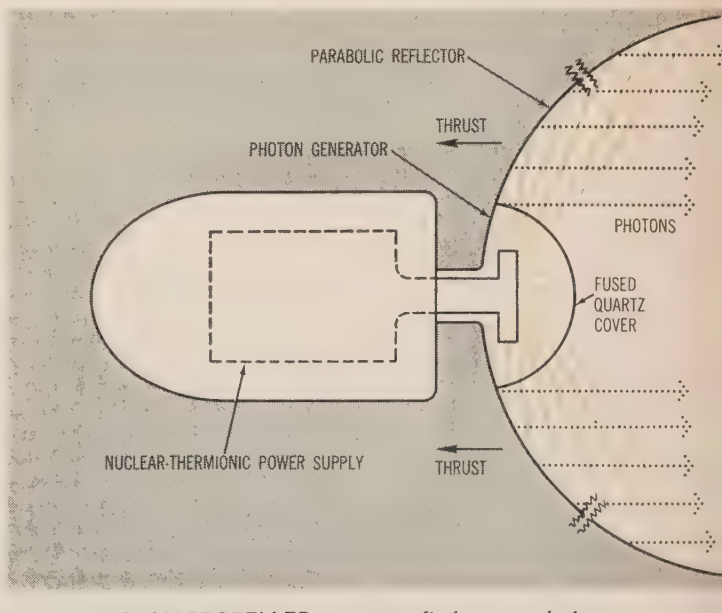
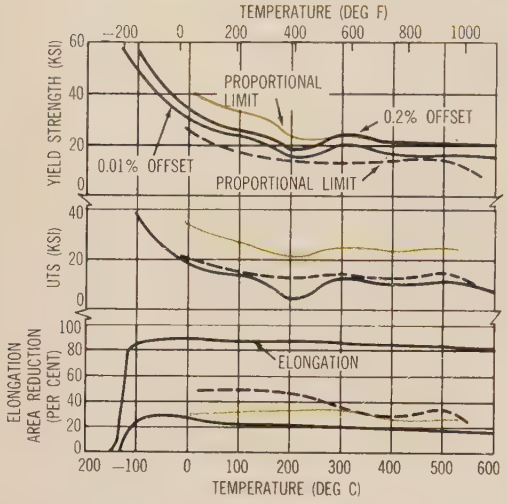


SMALL PHOTON-PROPELLED spacecraft has a photon generator that probably would produce a gaseous nuclear phase reaction and a two-acre reflector.



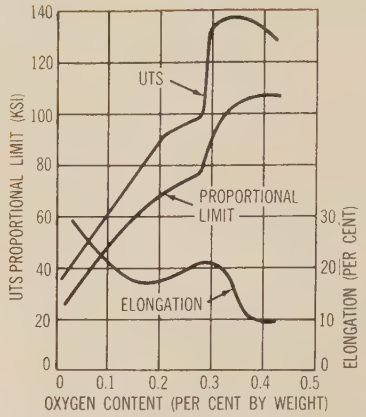


FIGURE 1: Effect of temperature on columbium's tensile properties (left). The data are from Vaughan and Rose (0.02 mm average grain size, argon atmosphere or vacuum; color curves, Westinghouse 0.001 in./in./sec strain rate, 0.5 mm average grain size, air; solid black curves), and Tottle (protective atmosphere; dashed curves). Above: Effect of oxygen on columbium's room-temperature tensile properties as given by C. R. Tottle.

State of the art:

columbium and tantalum

For temperatures from 1800 to over 4000 deg F, promising heat-resistant metals are far and few between. Two of the prime candidates for these regimes are columbium and tantalum. Continuing as another of its series on high temperature materials, S/A here reviews the status of these important refractory metals.

by Irwin Stambler, Associate Editor

THE PROPERTIES of columbium that make it so attractive for high temperature use include its relatively high melting point of 2415 deg C (4280 deg F); its good ductility, which makes for easy fabrication at room temperature; and its low density of 8.57 gm/cm³. In addition, Stanford Research Institute points out in a recent report, "Mechanical Properties and Oxidation Resistance of Certain Refractory Metals," its major oxide has the relatively high melting point of 1500 deg C (2550 deg F).

One of columbium's main limitations is its poor high temperature oxidation resistance. However, Jaffee, of Battelle Memorial notes that recent work has already provided some oxidation resistance in strong columbium-rich alloys. Columbium is also susceptible to hardening

due to fairly rapid contamination by oxygen when heated in air above 1800 deg F. Another disadvantage is its low modulus of elasticity of 15×10^6 psi (at room temperature).

The mechanical properties of unalloyed columbium have been fairly well evaluated up to about 600 deg C, but very little work has been reported on the mechanical properties of columbium-base alloys. *Figure 1* shows temperature effects on the tensile properties of columbium. The yield strength shows a large increase below room temperature as is characteristic of BCC metals. Yield strength and ultimate tensile (UTS) decrease relatively little from room temperature to 600 deg C. The proportional-limit and UTS values of Rose and Vaughan are much above those reported by other researchers. There is so far no satisfactory explanation of this discrepancy. Part of the answer may lie in the grain size of the material used by Rose and Vaughan, which was one-twentieth of that of the Westinghouse material.

Oxygen content is important

Several investigations have shown the important effect of oxygen content on the mechanical properties as well as need for data on this variable for any worth-while comparison of test data (*Fig. 1*). In a study of the effect of cold work on the tensile properties of columbium, Vaughan and Rose rolled ⅛-in. sheet to 0.04 in. without any intermediate anneal. Their results show that the as-rolled material had UTS values about 60 per cent higher than the recrystallized metal as well as 75 per unit decrease in elongation. The UTS for as-rolled decreased very little with increasing temperature to 600 deg C. The proportional limit of the recrystallized material decreased over 50 per cent with increasing temperature to 600 deg C, while that for cold-rolled which was about 100 per cent above the value for recrystallized at room temperature—decreased only slightly.

Table I shows the effect of various solid-solution alloy additions on the room-temperature tensile properties. All additions caused the expected strengthening, 7.5 Mo being most effective. Tottle selected the 6¼ Mo alloy as giving a good balance between room-temperature strengthening and fabricability. In other tests, Semmel found that cerium additions greatly improve columbium's workability (*Table III*).

Saller, Stacy, and Porembka have run short-time stress-rupture tests on columbium, Cb-Ti alloys, tantalum, and molybdenum at 2200 deg F in a helium atmosphere. The Cb-Ti system was studied because it proved to be the one easiest to fabricate among a number of binary columbium system. Later studies show that binary columbium alloys containing small additions of molybdenum, tantalum, ranadium, and zirconium can be fabricated by cold-working suitable conditions.

Saller, Stacy, and Porembka ran creep tests on the 10Ti alloy at 1800 deg F in a vacuum and on columbium in the recrystallized and cold-rolled conditions. The cold-rolled columbium showed a higher 100-hr rupture strength at 1800 deg F than the other materials. The 10Ti alloy had the lowest value, even though it

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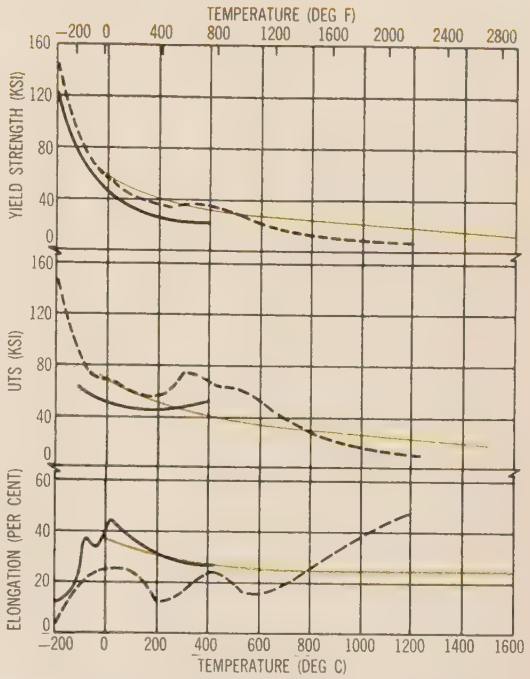


FIGURE 2: Effect of temperature on tantalum's tensile properties. Data are from Bechfold (air, 0.0003 in./in./sec strain rate, +50 grains per mm², 1.25 kn. gage length; solid black curves), Pugh (vacuum, 0.0015 in./in./sec strain rate, 130 grains per mm², two inches gage length; dashed curves), and Kattus and Dotson (air, 0.1 in./in./sec strain rate, 10 seconds holding time, two inches gage length; color curves). Kattus and Dotson also reported roughly 5000 psi UTS and 49 per cent elongation at 5000 deg F.

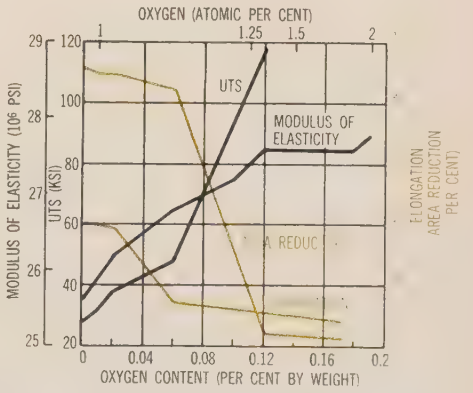


FIGURE 3: Variation of tantalum's room-temperature properties with oxygen content as given by Gebhardt and Preisendanz.

Table I: Room-Temperature Tensile Properties of Binary Columbium Alloys[1]

Alloying Element (per cent)	Proportional Limit (ksi)	Tensile Strength (ksi)	Elongation (per cent)
Columbium base	28.2	41.1	29
Molybdenum			
5[2]	54.2	67.2	8
5	48.8	59.1	12
5	54.4	60.5	17
6.25		84.2	15
7.5	69.2	90	13
10	53.2	69.4	8.5
Platinum			
1	31.5	43.5	13
Tantalum			
10	44.1	59.9	11
10	46.6	64.3	20
Titanium			
2	31.6	40.3	15
5	48.6	55.3	15
Tungsten			
5	29.8	44.6	9
5	48.6	58.2	12
7.5	56.9	75.5	10
10	57.8	66.5	10
Vanadium			
2	42.3	55.8	11
Zirconium			
1	24	42.1	18
2	31.6	44.8	12

(1) From Tottle, "Physical and Mechanical Properties of "Columbium," J. Inst. Metals, 85/4 ('57). (2) More than 0.05 per cent O_2 content.

Tungsten Additions (per cent)		Molybdenum Additions (per cent)	
By Weight	Atomic	By Weight	Atomic
1.20	1.18	0.40	0.78
5.20	5.12	2.2	4.2
10.40	10.25	5.20	9.6
20.4	20.2	11.2	19.7

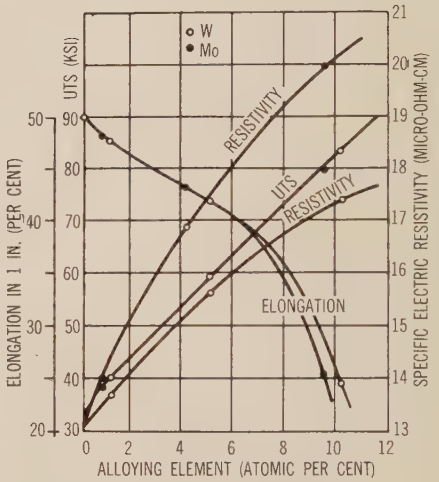


FIGURE 4: Changes in the room-temperature properties of tantalum with additions of tungsten (circles) and molybdenum (bullets).

showed superior short-time creep-rupture properties at 2200 deg F.

Stress-rupture tests by Begley on recrystallized and cold-rolled columbium at 1800 deg F show values of 33,000 and 28,000 psi—twice as high as those obtained by Saller. Begley's alloys, though contained 0.6-0.7 per cent zirconium. Less than one per cent more zirconium apparently doubled the rupture strength.

Michael reports some stress-rupture tests on columbium and 31Ta and 0.51Zr alloys at 2000 deg F in an argon atmosphere. The creep tests were made on specimens machined from 0.32-in.-diameter as-swaged rods prepared from arc-cast ingots. The 100-hr rupture strengths were: columbium, 13,000 psi; 0.51Zr, alloy 18,800 psi; 31.2Ta alloy, 17,500 psi. These data confirm Begley's report that zirconium is a very effective solid-solution strengthening addition. However, the 0.51Zr alloy was reported to oxidize at the same rate as unalloyed columbium at 2000 deg F, as against a 95 per cent lower rate for 31Ta. This alloy has almost as high a 100-hr rupture strength as 0.51Zr and a higher 500-hr strength (about 13,500 vs 11,500 psi).

The oxidation properties of columbium have been studied fairly extensively. Three oxides have been reported by Brauer: CbO_2, CbO, and Cb_2O_5. The last, which is the major oxide, has been reported to have three forms. Its low temperature form is said to be stable up to 900 deg C; the medium temperature form, to 900-1100 deg C; and high temperature form, to above 1100 deg C. Kling recently suggested that Cb_2O_5 exists in only two forms that are true phases. Generally, studies show that the oxidation of columbium follows a parabolic-rate law from 200 to 375 deg C and a linear-rate law from 400 to 1200 deg C.

Michael has reported the results of some interesting studies on the oxidation of Cb-base alloys. Initial screening tests were run on a number of binary and ternary columbium alloy samples cut from arc-melted buttons. The binary alloys that showed the best oxidation resistance were 30W, 20Cr, 20Al and Cb-20Si. The best ternary alloys appeared to be in the range of 12-20Cr and 8-12Co. The more promising alloys were studied further over longer times at 2000 deg F. These tests clearly showed that the 20Cr-12Co alloy was most oxidation-resistant at 20000 deg F.

Other tests on a series of Cb-Ta alloys showed 20Ta

to be particularly interesting. Tests with further additions showed the best alloy in this group to be 20Ta-25Cr-12Co. However, Michael reported it to be not as good as the 20Ct-12Co.

As Jaffee notes, intensive work on columbium alloys has led to a number of promising proprietary materials. General Electric, he notes, has developed an alloy family called the "F-series," in which F-48 (15W-5Mo-12Zr) has the highest strength properties. Other promising alloys have been developed by du Pont, Fansteel, Kennecott, and Union Carbide Metals.

Jaffee concludes that "solid-solution strengthening of columbium through the use of elements like tungsten, tantalum, molybdenum, and vanadium by reaction between zirconium and other components of the alloys, including carbon or other alloy additions, appears to be effective in strengthening, although less is known about this aspect of the strength problem. Large contents of titanium or zirconium have been found to be disadvantageous from the viewpoint of developing high temperature strength, although the higher titanium contents are very beneficial in improving ductility, fabricability, and oxidation resistance."

Tantalum has a high-melting oxide

Tantalum is attractive for high temperature use because of its high melting point of 2996 deg C (5425 deg F) and because that its oxide is effectively not volatile below about 2500 deg F. Tantalum is very ductile at room temperature and can be readily formed or fabricated. Its main disadvantages are its relatively poor oxidation resistance at high temperature (though it's better in this respect than some other refractory metals) and its fairly high density of 16.6 gm/cm^3.

Most of the mechanical-property data on tantalum have been reported over the past five years, based mainly on studies by Bechtold, Pugh, and Kattus. The tantalum used by these three researchers can be from Fansteel.

Table II gives room-temperature tensile data for annealed tantalum. Particularly interesting is the sensitivity of yield strength and UTS to the rate of straining shown by the data from Kattus and Michael. Little, if any, effect of the strain rate on ductility is reported by Michael, but Kattus, for a 2000:1 change in the strain rate, shows a significant decrease in ductility with increasing strain rate.

Figure 2 shows the effect of temperature on tantalum's mechanical properties. The tests by Pugh were run in a vacuum, these by Kattus and Dotson in air, as apparently were those by Bechtold. In the work of Kattus and Dotson, the specimen usually was heated to the test temperature in less than 20 seconds (by passing an electric current through it) and held at the test temperature for either 10 or 90 seconds before the test was started.

Pugh's UTS data show an anomalous increase between 200 and 800 deg C, which he ascribes to a strain-aging effect due to interstitial impurities. Bechtold's value at 400 deg C also shows an increase over that at 200 deg C.

The elongation data from these studies vary considerably. The two peaks in the curve based on Pugh's data are ascribed by him to strain-aging effects. He suggests that the double maximum may result from interaction between dislocations and interstitials, and that carbon and/or oxygen may account for the 50-deg C and nitrogen for the 400-deg C maximum. The

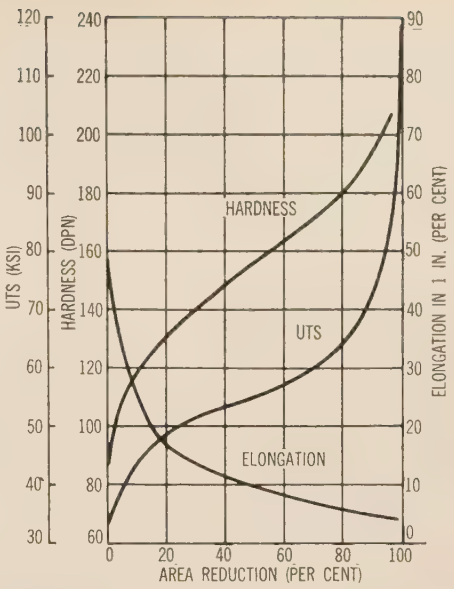


FIGURE 5: Effect of cold work on tantalum properties.

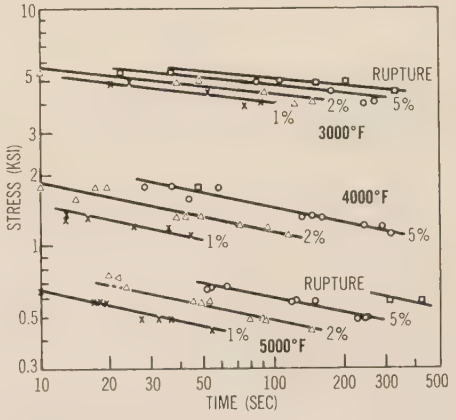


FIGURE 6: Short-time creep data for tantalum in argon atmosphere. Specimens were loaded at room temperature and heated rapidly to the test temperature. Data apparently show when creep-strain values were reached after the test temperature has been attained. Strain during heating under load is due about equally to thermal expansion and to creep.

temperatures at which the maxima occur are sensitive to the strain rate, with lower rates leading to shifts to lower temperatures.

Table IV gives the tensile results of two tantalum studies in air and argon for two strain rates and two holding times. These data again point to the marked effect of the strain rate on yield strength and UTS at all test temperatures.

Like columbium, tantalum absorbs, or getters, trace quantities of interstitial gases at elevated temperatures; at high temperatures, it releases these gases under suitable vacuum conditions. Small amounts of these interstitial elements, researchers have found, greatly in-

more on next page

Table II: Room-Temperature Tensile Data for Annealed Tantalum

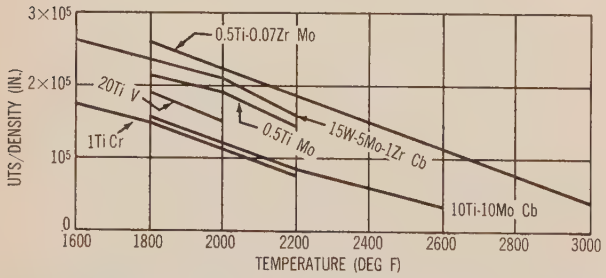
	Bechtold[A]	Pugh[B]	Kattus et al[C]		Michael[D]	
Nominal strain rate (in./in./sec)	0.0003	0.090	0.00005	0.09	0.0003	0.02
Modulus of elasticity (psi)			25.7×10^6	25.7×10^6	27×10^6	
Yield strength (0.2 per cent offset, psi)	39,300[E]	57,350	32,700	54,100	42,000[E]	57,000[E]
Ultimate tensile strength (psi)	49,800	67,140	44,600	61,800	58,000	67,000
Elongation (per cent)	45[F]	25.3[G]	46.3[G]	34.2[G]	38[H]	38[H]
Area reduction (per cent)	86				84	82

(A) "Tensile Properties of Annealed Tantalum at Low Temperatures," Acta Met 3 ;5 ('55). (B) "Temperature Dependence of the Tensile Properties of Tantalum," ASM Trans , 48 /677 688 ('56). (C) Southern Research Inst. Rept. WADC-Tr-55-391, '55 (D) "Mechanical Behavior and Working of Tungsten, Molybdenum, Tantalum, and Columbium," Fansteel Metallurgy, 57. (E) For proportional limit. (F) In 1 25-in reduced gage section. (G) In two-inch reduced gage section. (H) Gage section not specified.

Table III: Room Temperature Tensile Properties of Cb-5Ce Alloy*

	As-Rolled	Recrystallized
Ultimate tensile strength (psi)	128,000	84,000
Yield strength (0.2 per cent offset, psi)	104,000	65,000
Elongation (per cent)	0.8	27

*From J. W. Semmel Chemical analyses of the sheet material showed 0.55 per cent cerium and 0.033 per cent O_2. Properties after recrystallization for one hour at 1540 deg C Crosshead speed was 0.05 ipm.



COMPARISON of tensile strengths of some columbium alloys with those of other refractory alloys.

crease the tensile strength of tantalum and decrease the ductility. *Figure 3* shows the effect of oxygen content on tantalum's room-temperature tensile properties.

Figure 5 shows the effect of cold work on tantalum properties. A 95 per cent area reduction resulted in almost a 200 per cent increase in UTS, with a decrease in elongation from 50 to five per cent. Cold-worked tantalum is available commercially with a room temperature tensile-strength range of 100,-150,000 psi.

Myers has studied the effect of tungsten and molybdenum additions on the room-temperature hardness, tensile strength, and elongation of tantalum. The metals he used were all 99.95 per cent pure or better. Pressed alloy powders were put through a sintering and swaging schedule that produced with 0.1-in.-diameter rod as the test material. (The two alloys with the largest additions of tungsten and molybdenum respectively, were studied as sintered, since they proved too brittle for swaging.)

Myers found that UTS increases almost linearly with the alloying addition (in atomic per cent). He also reports the same effect for hardness up to additions of 20 atomic per cent (*Fig. 4*).

Effects of cold work studied

Myers also studied the effect of cold work on tantalum alloyed with tungsten and molybdenum. By wire-drawing annealed 0.1-in. alloy rods the tests show that the five and ten per cent alloys (atomic) work-harden much more quickly than pure tantalum or the one per cent alloys. Also, in all cases, the initial 20 per cent reduction produced a marked rise in UTS; further deformation was less effective until the range of about 60-80 per cent was reached. The elongation for all alloys dropped sharply after 20 per cent cold work—but the alloys still showed 2-5 per cent elongation after 90 per cent cold work.

To study the effect of tungsten and molybdenum additions on the annealing temperature of tantalum, Myers measured the hardness after a ½-hour anneal at temperatures from 500 to 2600 deg C. Additions of one, five, and 10 per cent tungsten had no apparent effect on the annealing temperature of material that had been cold-worked 20 per cent, but raised the temperature at which quick recovery begins by about 100 deg C for 80 per cent cold-worked material. Additions of molybdenum in the same amounts increased the temperature at which quick recovery begins by about 100 deg C for all degrees of cold work from 20- to 80 per cent.

Short-time creep tests have been run by Kattus and Dotson and Preston, Roe, and Kattus in air and in argon at up to 5000 deg F (*Fig. 6*). Some data obtained at Battelle on creep at 1200 deg F for tantalum containing various amounts of interstitial elements have been reported by Klopp and others. The gas content of sintered, degassed tantalum was substantially lower than that of arc-cast, arc-rolled; arc-cast, anenaled; and sintered, annealed material. The sintered, degassed tantalum also show much less creep strength than the other three materials. It had a larger grain size, be-

cause of the very higher temperatures of the degassing treatment.

On the basis of observations on other materials, the larger grain size could be expected to give a more creep-resistant material, other factors remaining constant. So the lower creep strength of the sintered, degassed tantalum evidently results from a lower interstitial content.

The oxidation characteristics of tantalum have been studied fairly extensively. Oxidation has been reported to follow a logarithmic law below 300 deg C, a parabolic-rate law from 325 to 500 deg C, and a linear-rate law from 500 to 1000 deg C. The oxide is essentially Ta_2O_5 and has been reported to be extremely adherent but very porous.

Michael has reported the results of oxidation studies on a number of binary and ternary tantalum alloys, based on the displacement of the metal interface after 16 hours in air at 2000 deg F. The binary alloys that showed a significant improvement included 30Ti, 30Fe, 10Cr, and 10Ni; however, the Ta-30Fe was reported to be brittle. The ternary alloys that showed significant improvement were 33Ti-18Co, 20Cr-12Ni, and 20Cr-12Co.—End

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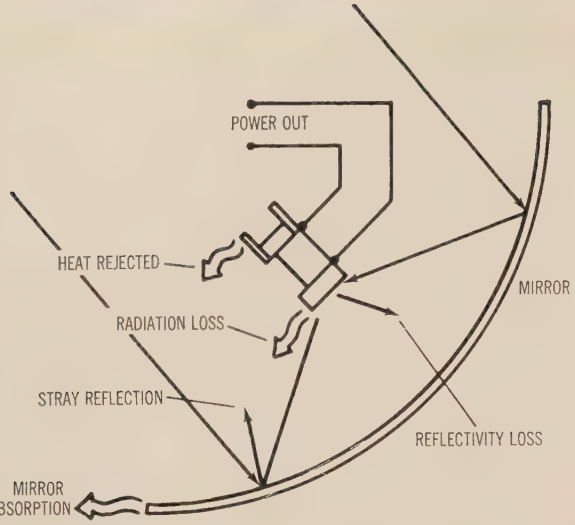
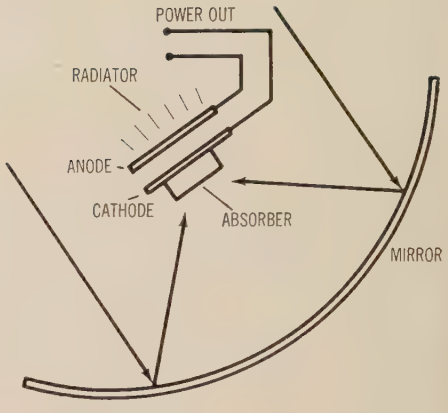
Table IV: Effect of Strain Rate on Tantalum Properties*

Temperature (deg F)	AIR High Rate 10 Seconds	AIR High Rate 90 Seconds	AIR Low Rate 10 Seconds	AIR Low Rate 90 Seconds	Temperature (deg F)	ARGON High Rate 10 Seconds	ARGON High Rate 90 Seconds	ARGON Low Rate 10 Seconds	ARGON Low Rate 90 Seconds
Yield Strength (ksi)									
80	54.1		32.7		3000	7.49	6.96	3.78	3.86
1500	18.2	13.9	6.62	8.4	3500			0.61	0.79
2800	11.9				4000	1.76	1.61		0.42
					5000	1.29	1.17		
Ultimate Tensile Strength (ksi)									
80	61.8		44.6		3000	10.7	10.8	4.03	4.12
1500	25.5	27.3	17.2	19.9	3500			0.92	1.81
2800	15.5				4000	3.69	3.95		0.42
5000	6.8				5000	2.34	2.06		
Elongation (per cent)									
80	34.2		46.3		3000	29.7	30.2	19.0	19.3
1500	23.5	25.8	20.5		4000	43.5	46.0		
2800	23				5000	47.8	50.8		
	48.7								

*From Kattus & Dotson and Preston, Roe & Kattus.





THERMOELECTRIC converters (left) have hot-junction temperatures ranging from 500 to 1200 deg F. Only about 35 per cent of the intercepted solar energy reaches the converter. The rest is absorbed as heat by the mirror, reradiated by the converter, or otherwise dissipated. Right: Thermionic generator temperatures range from 1600 to 3200 deg F, making thermionic designs more efficient than thermoelectric ones.

Non-propulsive power

for advanced vehicles—III

This is the third and last article in a series on non-propulsive power systems. It reviews fuel-cell, solar, and nuclear designs —advanced systems that are now in the lab stage but should be ready for flight application within five years.

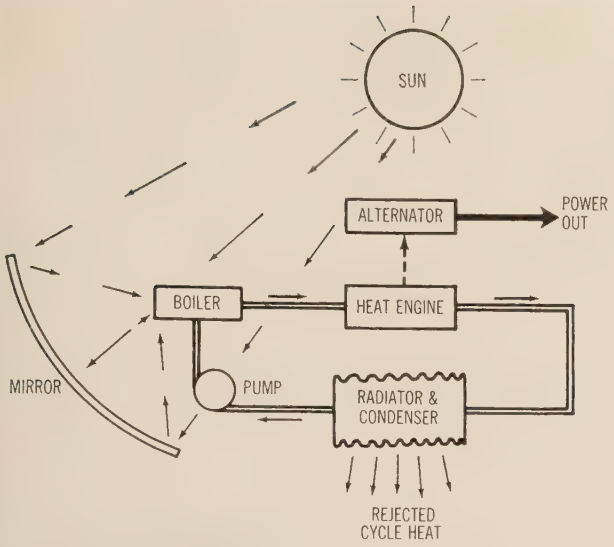
by Robert W. Curran, Senior Group Engineer, Physics Staff, Aero-Space Div., Boeing Airplane Co.*

THE FUEL CELL basically is a chemically fueled device that converts chemical energy directly to electrical power. Among the cells studied for aerospace applications, the most advanced is an open-cycle type in which hydrogen combines with oxygen to form water and produce electrical power. Other fuels can be used, too, but so far none of these appears likely to equal the hydrogen-oxygen combination in performance.

Hydrogen-oxygen cells can also be operated in a closed cycle, in which the water byproduct from the cell is converted back to hydrogen and oxygen through electrolysis. There are hopes that research will make it possible to use solar radiation or heat directly to break down the water—whatever else the byproduct may be, if the cell is not a hydrogen-oxygen type—into its constituent parts for reprocessing through the cell.

The closed-cycle cell is admittedly inefficient. Nevertheless, combined with a solar-energy collector, it could prove superior to the present solar-cell storage battery power systems.

* Aerospace Div., Boeing Airplane Co., P.O. Box 3707, Seattle 24, Wash. This series is a condensation of a paper, "The Applicability of Nonpropulsive Power to Space Vehicles," given at the Vickers Aircraft Hydraulic Conference in Detroit, Mich., last November.



DYNAMIC CONVERSION of solar heat to electricity is more advanced than are static-conversion techniques. Its operational success depends on the development of light mirrors and reliable conversion hardware.

Fuel cells look good because (in the lab) their efficiency is so much better than that of competing equipment. Open-cycle units can operate with a fuel consumption of 0.75 lb/hp-hr, using 0.125 lb hydrogen for every pound of oxygen. Compare this with the 3:1 hydrogen-oxygen ratio of the open-cycle heat engine, and you see that the fuel cell has a tremendous advantage in tankage volume.

Another advantage is that fuel cells have few, if any, moving parts that could fail in operation. They also do not affect vehicle attitude and stability in space.

Now the other side of the coin: A fuel cell is much heavier than its mechanical counterpart. Despite its lower fuel consumption, it does not make up this weight handicap until mission times exceed about three days.

Fuel cells are stable under steady electric loads. However, sudden peak demands can cause electrode flooding that may drown the cell action. The complicated control system that you need to guard against this danger hurts the reliability.

Like batteries, a fuel cell can only put out dc power. Any conversion to another form of energy means a loss in efficiency. Another point is that the fuel cell may be adversely affected by zero gravity.

Lastly, present cell electrodes have a limited life. Unless this problem is solved, it is difficult to see how fuel cells can be used for space missions.

Fuel cell engineers are confident they can lick the major problems. If they come up with the open-cycle designs that they claim are feasible, then the fuel cell will fit space missions lasting more than three days and with power demands in the range of 1-5 kw. (Lunar flights and deep-space probes come under this heading.) Fuel cells could also replace the batteries in closed-cycle solar power systems.

Solar energy can be used in several different ways to generate non-propulsive power. The three processes that look most likely for aerospace vehicles are:

- photovoltaic conversion of solar energy to electric power,
- static conversion of solar heat to electric power,
- dynamic conversion of solar heat to electric power.

Photovoltaic systems are made up of a group of devices, like silicon cells, that can convert the sun's energy into electricity. Such devices can provide "excess" power to handle operating-equipment loads and also charge storage batteries that provide power during dark-side operation. Usually, an orientation system is needed to keep the cells at their highest output level.

Large cell arrays are hard to stow

Any solar cell must face the sun to perform efficiently. Fortunately, the output drops off in a cosine function, so that an orientation accuracy of ±15 deg is acceptable. Not so with competing solar power devices, for which the accuracy often must be held to within 0.5 deg, and sometimes even to 0.1 deg.

The 10 per cent overall efficiency of present photovoltaic system designs is three times better than that of any other present solar system, and therefore the area it takes up is proportionately smaller. Another advantage of the photovoltaic system is that the cell-array configuration does not have to be precise. Quite the opposite is true for the mirror designs used in other solar conversion techniques. Also, the weight of the array does not increase with mission time.

Photovoltaic systems also have several shortcomings. As you increase the size of a solar cell, the internal IR loss goes up and the efficiency falls off. It's for this reason that you need as many as 56,000 separate cells to get one-kilowatt output capability in sunlight. And then you may have to boost this number by as much as 65 per cent to provide extra power for dark-side storage.

Every one of these thousands of cells must be electrically connected to the power distribution system. Every connection is a possible failure point. Now consider that the array must be collapsible or retractable, and you realize what a reliability problem you have on your hands.

Photovoltaic cell arrays must be stored and protected against damage during launch, re-entry, and soft impacts. Therefore, any vehicle that depends upon solar power for its "life" must carry a separate power system for launch, re-entry, and impact.

Cost is high, too. Today, the cells needed to deliver one kilowatt of power cost an estimated $420,000. By 1965, they should cost 40 per cent less—but $252,000 still isn't peanuts.

Orientation accuracy must be ±15°

Large solar-cell arrays are hard to stow; when extended for operation in space, they can be damaged by meteorites. At altitudes below 200 nm, the array also has an appreciable aerodynamic drag. Re-entry weights are high compared with those of open-cycle chemically fueled systems. Finally, applied electric loads must be carefully matched to cell impedance, which complicates the design of the powered equipment.

Despite these disadvantages, the solar photovoltaic power system is without competition for long operating times during which the average power does not rise

more on next page

above 3-5 kw—and there is no high peak demand. At power levels above five kilowatts, the nuclear system becomes attractive. If the mission is short—say, 10-14 days—the hydrogen-oxygen-fueled engine and possibly the open-cycle fuel cell becomes competitive.

Static conversion of solar energy involves a two-step process. First the sun's radiant energy is collected by a mirror and focused or otherwise concentrated to heat up an absorber. Heat then is transferred from the absorber to a static conversion device that produces electric power and rejects waste heat to a radiator.

Two types of static heat-to-electricity generators are now being considered:

- The thermoelectric generator relies on the Peltier effect. It acts much like a simple thermocouple to generate an electric voltage as a function of the temperature difference between the hot and the cold junctions of two dissimilar metal conductors. Most thermoelectric generators operate with a hot-junction temperature of 500-1200 deg F.
- The thermionic generator relies on the temperature difference between an absorber and a radiator. The thermal energy from the absorber drives electrons from a thermionic cathode to a radiator-cooled anode. Because its operational temperature levels (1600-3200 deg F) are higher than those of the thermoelectric generator, the thermionic generator has the better conversion efficiency.

Static-conversion systems should prove a lot less expensive than their photovoltaic counterparts. Reliability should also be better, because probably fewer generators than photovoltaic cells are needed to produce a given power.

The mirror poses the worst problem

The mirror is the big problem with static-conversion devices. Its curvature must be held quite exactly, and the assembly must be precisely oriented to intercept the sun's rays at the best angle. Researchers believe it will be difficult to build a mirror-absorber combination that can deliver 35 per cent of the intercepted solar energy to the generator. With a 10 per cent conversion efficiency, the overall system efficiency is only 3.5 per cent.

A lot more development work must be carried out before static-conversion techniques can challenge the photovoltaic systems. Unless accurate, light, and cheap mirrors can be developed—in combination with efficient static generators—the static solar converter isn't worth considering for space vehicles. At the least, conversion efficiencies must be improved by a factor of two or three.

Dynamic and static conversion of solar heat to electricity are much the same, with one major exception: in the dynamic process, the heat is converted to electricity in two steps instead of one. First a turbine or reciprocating engine converts thermal energy to mechanical power, next, the engine shaft power is used to drive an alternator.

Such a scheme has several advantages. For instance, it may be possible to use the same power-generating equipment during all flight phases by substituting an energy source for the solar collector during launch and re-entry. (An expendable heat sink would have to be added in place of the radiator during re-entry.)

If the mechanical heat engine had a sufficiently high thermal efficiency, it might be possible to eliminate batteries for dark-side power—heat energy could be stored during the solar cycle for later use. Such an arrangement would be lighter and more reliable than the battery system. The alternator could also produce a variety of voltages and frequencies without any intermediate conversion.

On the negative side, dynamic conversion again poses mirror problems—on top of thermomechanical complications. Rotating hardware, for example, does not have nearly the life potential of static devices. Also the handling of boiling and condensing heat transfer fluids under zero-gravity conditions is a tricky job that can only lead to a more involved system design. Meteorite damage can cause complete system failure if the radiator is holed. (Static conversion devices, which use solid-fin radiators, don't have this problem.)

However, if these problems can be solved, there is no doubt that dynamic conversion systems would be used in applications calling for 3-5 kw of power for two weeks or more. Successful system design depends mainly on the development of light mirrors and reliable conversion hardware.

The only available long duration high power energy sources are nuclear. For space stations, lunar bases, and interplanetary vehicles—for which power levels of 10 kw and more will be needed for months—nuclear power systems are the obvious answer.

Two nuclear systems are being considered: one uses a radioactive isotope as a heat source; the other depends on controlled fission within a reactor. Isotope systems, which are limited to the lower power levels, are usually considered for use with static converters like those in the solar systems. Reactor systems use mechanical heat engines and standard thermodynamic cycles to convert heat to power. Both types of systems need a radiator to reject cycle waste heat.

Most of the advantages of nuclear designs are not hard to spot. These units can put out a continuous flow of power for extended missions without large quantities of fuel. Since sunlight plays no role, they can be used on the moon, where you have long periods of extended darkness. The volume occupied by a nuclear system may be lower than that of solar power systems, particularly in the power ranges above five kilowatts.

Nuclear systems have drawbacks, too

Unfortunately the disadvantages of nuclear systems are also quite distinct and will often cause the vehicle designer to favor competitive systems despite their power performance. The severe radiation hazard can only be offset by heavy shielding—1400 lb of shadow shielding, for example, to protect a crew from a 20-kw reactor that is 50 ft away. The vehicle designer is faced with ground handling problems, questionable re-entry durability and performance, and political uncertainties.

System weights, fixed as a function of power, are generally high. They do not decrease with time, as is the case for competitive chemical systems. Lunar landing, lunar launch, and re-entry therefore are made more difficult. Nuclear systems also cannot be used during launch and re-entry, because of the radiation hazard and because the radiator is ineffective during these flight phases. In reactor power systems, heat sink radiators contain the cycle working fluid, so that system operation can be cut off by meteorite damage.

Nuclear systems are without competition in the high power, long-duration range. However, in the middle range, nuclear equipment will be competing—with solar power systems and, in some cases, the open-cycle fuel cell.—End

design progress

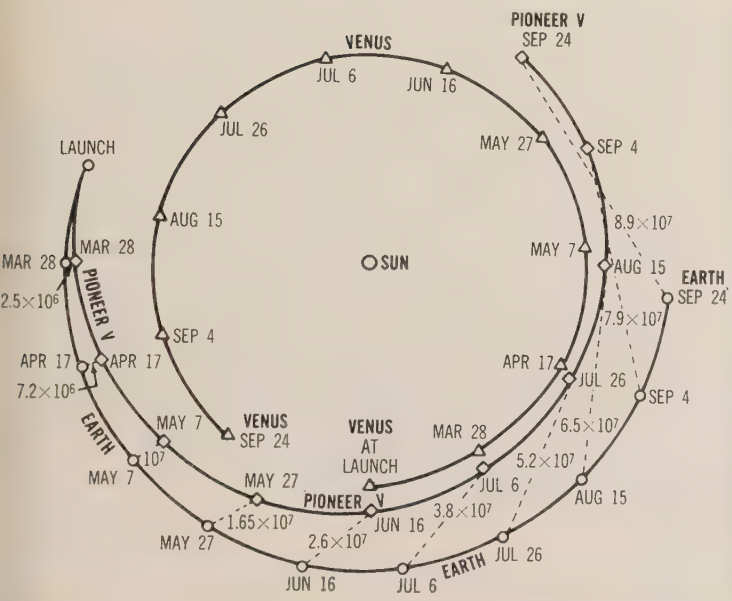
Pioneer V:

first planet made in U. S.

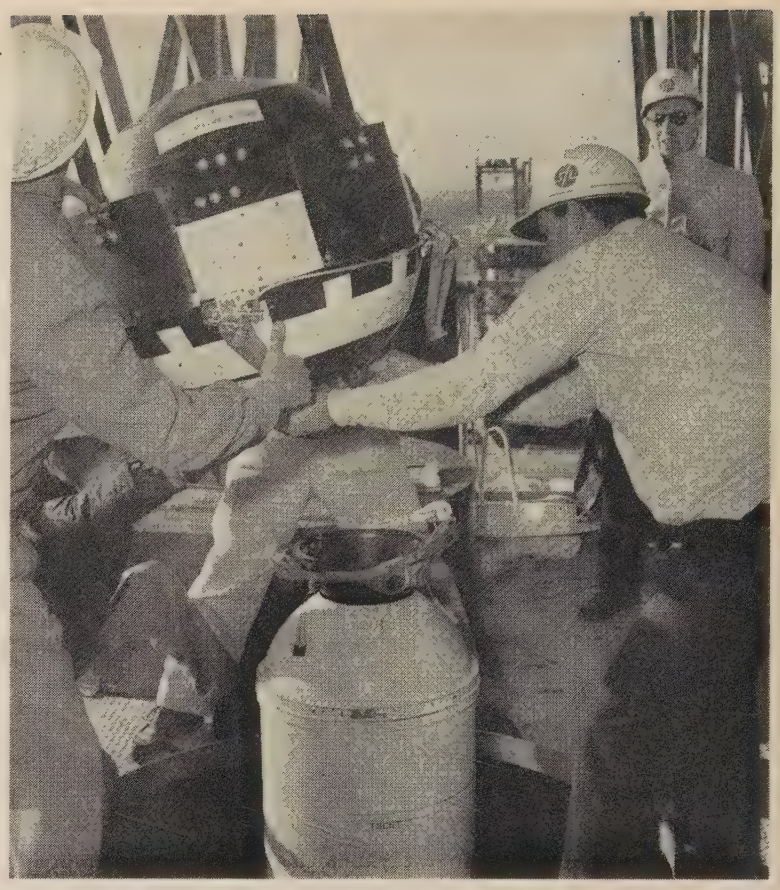
by Victor de Biasi, Associate Editor*

ON MARCH 12, the U.S. successfully launched the Pioneer V deep-space probe into a planetary orbit about the sun. Space Technology Labs, system manager for the project, reports its mission is to explore space out to about 50,000,000 miles, the maximum range of present communications facilities. Near the end of 1963, Pioneer V will come within 15,000,000 miles of Venus; in 1965, it will return to the vicinity of the earth. Its 95 lb weight breaks down into: structure, 11.5 lb; platform and wiring, 7.2 lb; instrumentation, 36.5 lb; experimental equipments, 9.9 lb; batteries, 17.2 lb; paddles and solar cells, 10.5 lb; temperature control material, 0.7 lb; dynamic balance weights, 1.5 lb. The instrumentation consists of sensing and measuring equipment for the scientific experiments, a Telebit telemetry unit, a Doppler transponder, a solar-cell power conversion system, and logic circuits. The launch vehicle was similar to that used for the Explorer VI satellite. The first stage was a standard Thor IRBM with a modified autopilot system, the second stage used an Aerojet AJ-101A engine and STL autopilot and radio guidance equipment, and the third stage used an Allegany Ballistics 248A4 solid propellant rocket. (See also *"Pioneer V's UHF Link Covers 50 Million Miles of Space," p. 162.*)

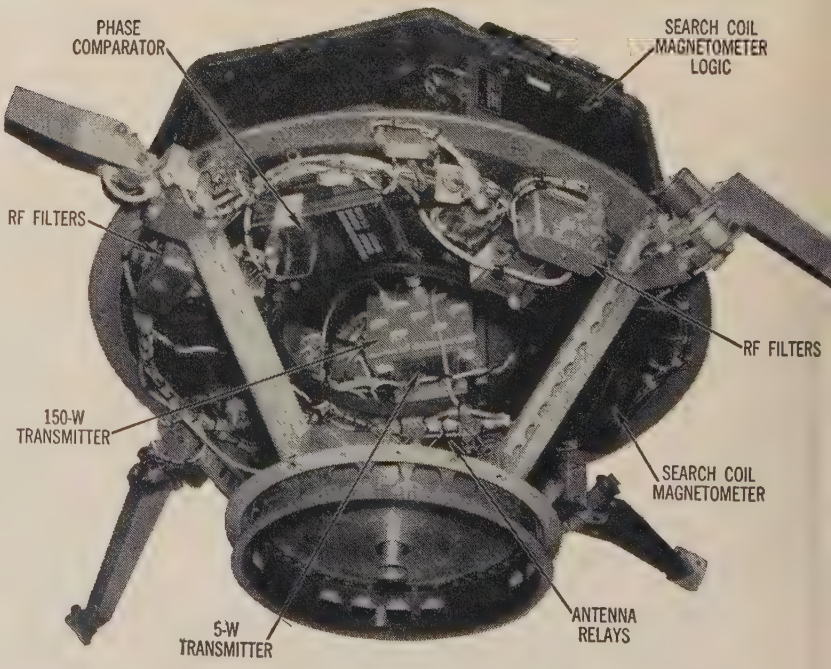
* Based on data supplied by Paul F. Glaser and Eugene R. Spangler, Staff Engineers, Space Technology Laboratories, Inc., P. O. Box 95001, Los Angeles, Calif.



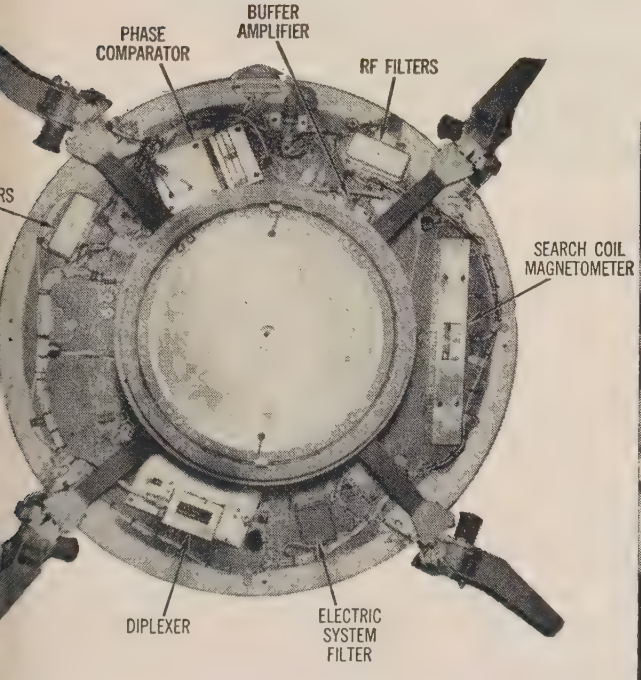
▲ **ORBIT** of Pioneer V for its first 300 days of flight. Distances (dashed lines) are in miles.



WORKMEN lower the Pioneer V payload onto the third stage of the launch vehicle, attach the solar-cell paddles, and put on the nose fairing. The four solar-cell paddles fold down for installation about the third-fourth interstage. At second-stage shutdown, some time after the nose fairing has been jettisoned, the paddles are released. They are then launched into their position before spin-up and third-stage firing. They consist of a central, one-inch-diameter aluminum alloy tube to which 12 aluminum honeycomb modules are attached. Solar cells are mounted in series on each module. The paddles alternately extend 22.5 deg up and down, and each successive paddle is rotated 30 deg farther counterclockwise. These angles keep a fairly constant number of solar cells in the sunlight despite the vehicle's changing attitude with respect to the sun.



FOUR EXTRUDED aluminum beams form the basic support structure of Pioneer V. They end at the periphery of a fiberglass honeycomb platform. The structure and the installed assembly are enclosed by an aluminum alloy sheet metal housing. Pioneer V's instruments are designed to measure radiation, magnetic fields, and micrometeorite density. They consist of an ion chamber and a Geiger-Mueller tube from U. of Minnesota; a U. of Chicago proportional-counter telescope; a search-coil magnetometer; and a micrometeorite momentum spectrometer. From ground tracking data on Pioneer V's orbit, scientists hope to determine the length of the astronomical unit—the semi-major axis of the earth's orbit—to within 0.03 per cent or better. The present accuracy is believed to be within 0.04 per cent.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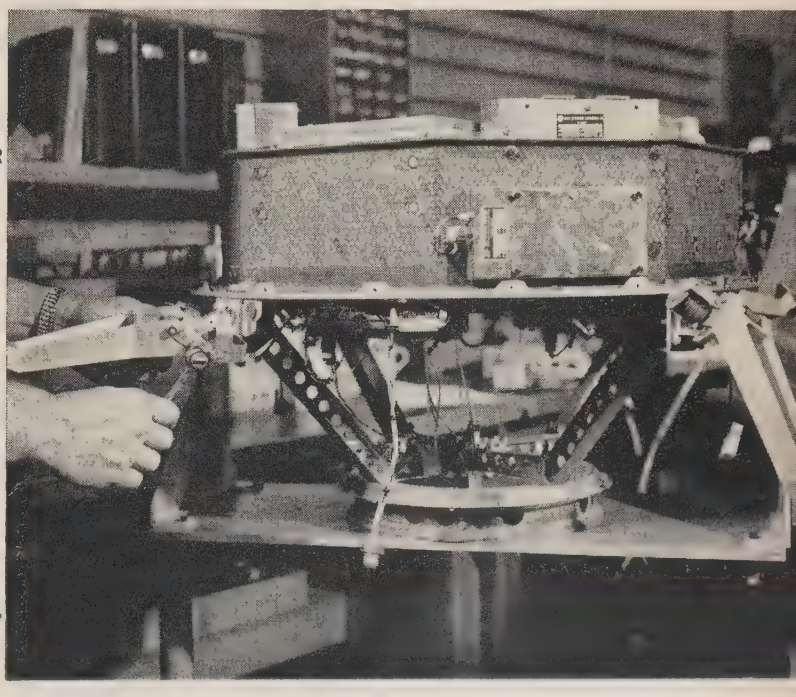

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Solving 3-D problems

made simple by stereographic projection

Many engineers have trouble visualizing the relationships between quantities in a three-dimensional problem. And yet this is an every-day problem that comes up again and again in the study of multi-gimbaled platforms, transformation of coordinates, resolution of angular velocities, interplanetary orbits, etc. This article, the first in a series of two, presents a simple stereographic projection that can be used for approximate solutions of three-dimensional problems involving angles.

by Sidney Godet, Research Director, Reeves Instrument Corp.[1]

UNLIKELY as it may sound at first, you *can* quite easily follow and solve the intricacies of a three-dimensional problem involving several coordinate systems—just as it's simple to drive through Boston once you know how.

In the mathematical problem, most engineers start out by drawing an isometric or perspective diagram. The trouble is, after four or five angles are drawn in, the diagram usually is a confusing mess of crossing lines.

It is easier to see the problem and its solution if you project the angles involved onto an imaginary sphere and transform the surface of this sphere to any of several flat projections. The most convenient of these projections is the stereographic.[2] It is easy to learn, can be used for a fast approximate solution to the most complicated problems, and can provide short-cuts to more exact solutions.

Let's start by analyzing a conventional isometric projection of three intersecting planes (*Fig. 1*). Vectors *1*, *2*, and *3*, which are the lines of intersection define the three planes. From these can be figured six angles: *a*, the plane angle between $\vec{2}$ and $\vec{3}$; *b*, the plane angle between $\vec{3}$ and $\vec{1}$; *c*, the plane angle between $\vec{1}$ and $\vec{2}$; *A*, the dihedral angle between planes *1-3* and *1-2*; *B*, the dihedral angle between *1-2* and *2-3*; and *C*, the dihedral angle between *2-3* and *1-3*.

Perspective is lost very quickly

This isometric is quite simple and easy to work with. But add a few more planes, each with some angular relationship to the others, and see what happens. You soon lose all perspective and start confusing lines and angles.

You can simplify the isometric by going to a sphere whose center is the point of intersection of the three planes (*Fig. 2*). Now look at the intersection of the planes with the surface of the sphere. All six angles defining the spatial relationship of the three planes show up in the spherical triangle: dihedral angles *A*, *B*, and *C* are represented by the vertex angles; plane angles *a*, *b*, and *c*, by the sides of the spherical triangle.

If you eliminate the three original planes, you can simplify the diagram. Draw a sphere and show only the lines of intersection of the three planes with the spherical surface (*Fig. 3*). Vectors *1*, *2*, and *3*, originating from the center of the sphere, are now represented by points

(1) Reeves Instrument Corp., Roosevelt Field, Garden City, N. Y.

(2) For details on stereographic projection, see Adams, "General Theory Polyconic Projections;" Coast & Geodetic Survey, Special Publ. 57. p. 24 to 72.

more on next page

on the surface. Any plane passing through the center forms a great circle and is drawn as an ellipse.

Unfortunately, it is rather difficult to draw such an ellipse accurately. You also can show only half a sphere. True, unseen intersections on the back half could be shown as dashed lines. But then you are cluttering up again. In any event, as you near the edge of the hemisphere, the lines become crowded and greatly distorted.

So far we have stayed with isometric projections. We started with a projection of three intersecting planes, constructed a sphere, and then eliminated the planes, so that we ended up with an isometric projection of the sphere.

From isometric to stereographic

In doing so, we have visualized the three-dimensional problem as a series of arcs and great circles on the surface of a sphere. Having learned this much, we can now go from the isometric projection, which proved impractical to the stereographic projection (*Fig. 4*).

Only the surface of the sphere is now projected. The projecting plane can be located anywhere as long as it is tangent to the sphere. The point of light, from which you make the projection, must be diametrically opposite the projecting plane.

Once you start working with stereographic projections, you find that they have a number of interesting properties:

- The projected area is not limited to a hemisphere. Over three-quarters of a sphere can be projected before the area distortion becomes too great.
- Projections are single-valued. Each point on the sphere, except for the projecting source itself, has one and only one corresponding point on the projection. Also, all angles are preserved intact.
- All great circles (planes passing through the center of the sphere) and small circles on the surface of the sphere project as circles. Circles through the projection source show up as straight lines.

Projection is a "primitive circle"

The projection of a great circle, every point of which is 90 deg from the projection source, or midway between the point source and the point of tangency of the projecting plane, is called a "primitive circle." This circle is the reference construction of stereographic projection on which all other constructions are built.

You must remember two laws of stereographic projection:

- The projection of any great circle intersects the primitive circle at two points that are 180 deg apart.
- If two points that are 180 deg apart on the sphere are projected, the straight line between the projected points passes through the point of tangency of the projecting plane.

Figure 5 shows the sphere without the intersecting planes of *Figure 3* in stereographic projection. Directions are again represented by points. Planes are represented by arcs of a circle. The point labeled "center" actually represents the point of tangency and not the center of the sphere.

Angular quantities (dihedral angles in space) are labeled in the usual manner. Arc lengths (plane angles in space) are labeled by centering the designation between two dots that represent the extremities of the arc. In this way, you don't clutter up the diagram with indicating arrows. Directions, or points on the projection, are indicated by a dot with a nearby designating character.

A stereographic projection is not a "pictorial" representation of three-dimensional problems. It doesn't look like anything the eye could see. It is an artificial shorthand for getting three-dimensional problems down on paper. With experience, however, you should be able to visualize the spatial geometry from the projection.

What are the basic construction techniques of stereographic projection? Let's start with the reference framework (*Fig. 6*).

Select a point of tangency for the projecting plane. This will be the center of your diagram. It usually represents some important direction in the problem, like vertical, north, east, earth's polar axis, first point of Aries, fore-aft vehicle axis, etc.

Using this point as a center, select a convenient radius and draw in the "primitive circle" (which represents the great circle whose pole is the point of tangency). As an exercise, draw in an arbitrary diameter—what you get is a great circle through the point of tangency.

Project great circle about pole

Now construct the projection of a great circle about a given point as the pole (*Fig. 7*):

- Draw a straight line through the given point P and the center C (*Fig. 7-A*).
- Erect a perpendicular to PC at C that intersects the primitive circle at A and B (*Fig. 7-B*).
- Draw in the perpendicular bisector of AP and label its intersection with PC as point D (*Fig. 7-C*).
- Draw line AD.
- Erect a perpendicular to AD at A and label its intersection with PC as point E (*Fig. 7-D*).
- Using E as the center and AE as the radius, draw a circle. This is the great circle with P as its pole (*Fig. 7-E*).

Next locate the projection of a point that is 180 deg away from a given point (*Fig. 8*):

- Draw a straight line through the given point P and the center C (*Fig. 8-A*).
- Erect a perpendicular to PC at C that intersects the primitive circle at A and B (*Fig. 8-B*).
- Draw line PA, erect a perpendicular at A, and label its intersection with line PC at point Q, which turns out to be the desired point 180 deg away (*Fig. 8-C*).

Go on to locate the poles of a given great circle (*Fig. 9*):

- Label the intersection of the great circle with the primitive circle as points A and B (*Fig. 9-A*).
- Draw the perpendicular bisector of AB (*Fig. 9-B*).
- Draw a tangent to the given circle at A and label its intersection with the perpendicular bisector as point D (*Fig. 9-C*).
- Lay off $DP{=}DQ{=}DA$ on line CD. Points P and Q are the poles of the given great circle (*Fig. 9-D*).

Great circle through given points

Construct a great circle through two given points (*Fig. 10*):

- Label the two given points as A and B (*Fig. 10-A*). Locate the point that is 180 degrees away from A and label it point D (*Fig. 10-B*).
- Draw the perpendicular bisectors of AB and BD and label their intersection as point E (*Fig. 10-C*).
- Using point E as the center, draw a circle through

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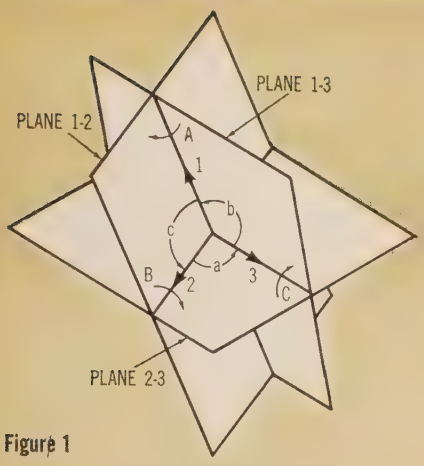


Figure 1

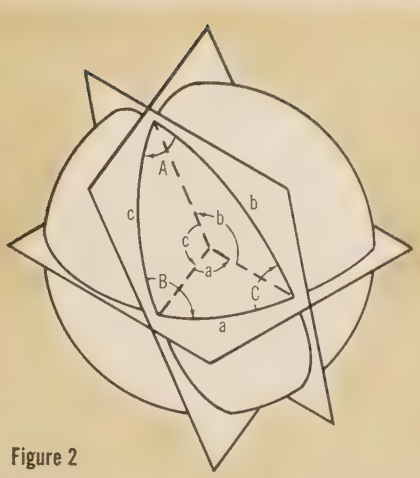


Figure 2

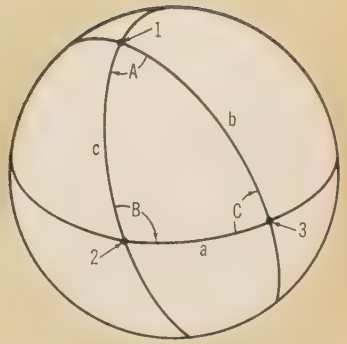


Figure 3

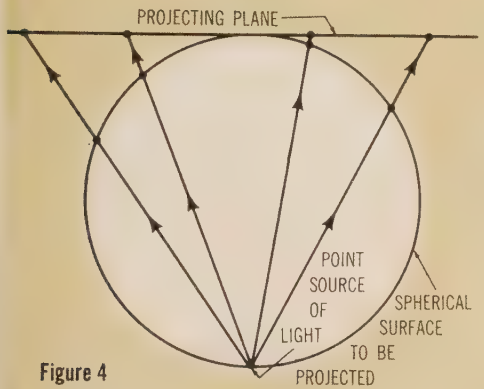


Figure 4

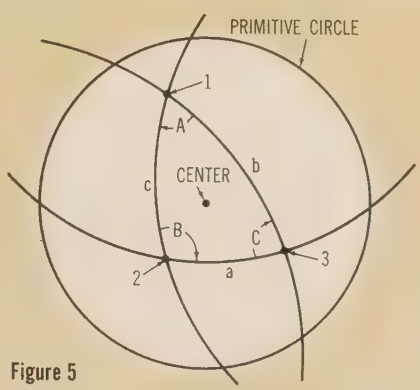


Figure 5

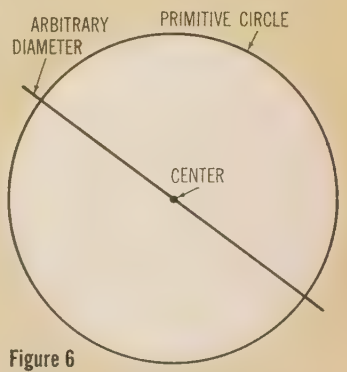


Figure 6

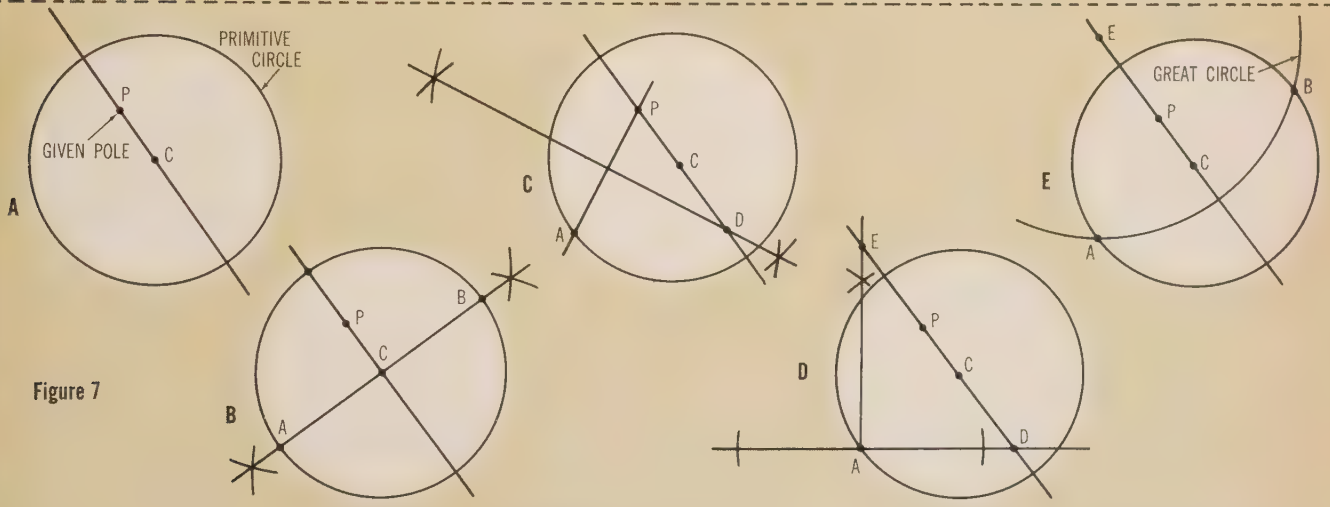


Figure 7

CONVENTIONAL isometric of three intersecting planes with subsequent addition of a sphere and removal of the planes; basic principle of stereographic projection; spherical surface in stereographic projection; reference framework for a stereographic projection; two stereographic constructions.

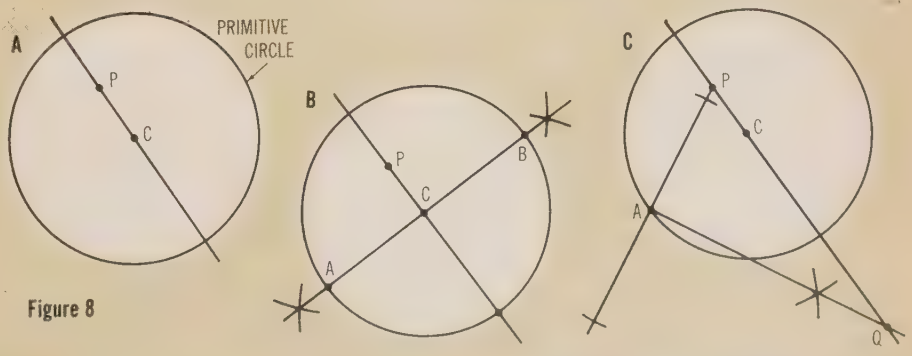


Figure 8

A, *B*, and *D* to describe the desired great circle (*Fig. 10-D*).

Once you have learned these basic construction techniques, you can go on to manipulating angular projections. As an example, construct a great circle through a given point on a given great circle and at a given desired angle (*Fig. 11*):

- Label the given point as *A*. Draw a straight line through *A* and the center *C*. Extend this line until it intersects the given great circle. Label the intersection as point *D*, which is 180 deg away from point *A* (*Fig. 11-A*).
- Forget about point *D*, and draw a tangent to the given great circle at *A*. Lay off the desired given angle *B* from the tangent, using *A* as the vertex (*Fig. 11-B*).
- Erect a perpendicular to the new line at *A* (*Fig. 11-C*) For the special case of $B = 90$ deg, this perpendicular coincides with the original tangent.
- Draw the perpendicular bisector of *AD*. Label its intersection with the other perpendicular as point *E* (*Fig. 11-D*).
- Using *E* as the center, draw a circle through *A* and *D* to describe the desired great circle (*Fig. 11-E*).

Locate point on given great circle

Now try to locate a point *Q* at a given arc length *B* from a given point *A* on a given great circle (*Fig. 12-A*). You should be able to work out the construction details for each step:

- Locate the pole *P* of the given great circle (*Fig. 12-B*).
- Draw the arc of a great circle through *P* and the given point *A* (*Fig. 12-C*).
- Draw the arc of another great circle through *P*, but this time at the given arc length, or angle *B*, with respect to the first great circle (*Fig. 12-D*). The intersection of this last great circle with the original great circle is the desired point *Q*.

Let's go on to a typical aerospace problem: Show the relationship between the azimuth, elevation, and traverse angles of a three-axis mount with the equivalent azimuth and elevation angles of a two-axis mount (*Fig. 13*). Let's use *A* for azimuth, *E* for elevation, and *T* for traverse for the three-axis mount, and *A′* for azimuth and *E′* for elevation for the two-axis mount, and assume the mounts are level and zero azimuth corresponds to north.

Several projections can be applied

Depending on where you choose to place your point projection source, you can make any number of stereographic projections to show the desired relationships:

- *The center of the projection corresponds to the vertical and the primitive circle to the horizontal plane (Fig. 13-A).* To construct, draw a line through north and the vertical. Lay off angle *A* and draw a radial line to mark it. Erect a perpendicular to this radial line at the center of the projection. Its intersection with the primitive circle marks the vertex of *E*.

Now construct a circle that passes through this vertex point at angle *E* with respect to the primitive circle. Lay off *T* along this circle from the intersection with the last radius you have drawn to locate the line of sight (which is a point at a given arc length from a given point on a given great circle). Draw a radial line through the vertical line and the line of sight.

- *The center of the projection corresponds to north, and the primitive circle is a vertical plane with east and west directions (Fig. 13-B).* To construct, draw a line through north and the vertical and a perpendicular line representing the horizontal plane. Now construct a circle that makes angle *A* with the north-vertical line at the vertical. Locate the pole of this circle. Construct a circle that makes angle *E* with the horizontal line at the pole.

Lay off *T* along this last circle from the intersection with the first circle to locate the line of sight. Finish by constructing a circle through the vertical and the line of sight (which is a circle through two given points).

Line of sight is placed at center

- *The center of the projection corresponds to the line of sight, and the primitive circle is a plane normal to the line of sight (Fig. 13-C).* To construct, draw a reference line (containing the vertical) through the line of sight. Lay off *E′* along this line from the line of sight to locate the intersection with the horizontal plane.

Construct a horizontal plane circle normal to the reference line. Locate the vertical, which is the pole of the horizontal plane circle.

Construct a north-vertical circle that makes angle *A′* with the reference line at the vertical point. Using the same method, construct a circle that makes angle *A* with the north-vertical circle at the vertical point. Locate the pole of this last circle (which is the vertex of angle *E*). Draw a line through this pole and the line of sight.

From three- to two-axis mounts

Now show the relationship between the train, cross-level, and elevation angles of a three-axis shipboard mount and the equivalent train and elevation angles of a two-axis mount (*Fig. 14*). Use designations *A* for train, *Z* for cross level, and *E* for elevation for the three-axis mount, *A′* for train and *E′* for elevation for the two-axis mount, and assume each mount is referenced with respect to the deck and zero train corresponds to the bow of the ship. In *Figure 14*, the centers of the three diagrams correspond to mast, bow, and line of sight, respectively. Here is how you construct these diagrams:

- *Figure 14-A*—Draw a line through bow and mast. Lay off *A* and draw the corresponding radial line. Construct a circle that makes angle *Z* with the primitive circle at the radius intersection.

Construct a second circle normal to the first. Lay off *E* along this circle from the intersection with the primitive circle to locate the line of sight. Draw a radial line through mast and line of sight.

- *Figure 14-B*—Draw in diameters normal to each other to represent bow-mast plane and deck. Construct a circle that makes angle *A* with the bow-mast plane at the mast. Construct a second circle that makes angle *Z* with the deck at the intersection.

Construct a circle normal to this second circle. Lay off *E* along the last circle from the deck intersect to locate the line of sight. Construct a circle through mast and line of sight.

- *Figure 14-C*—Draw a reference line through line of sight. This line contains the mast. Lay off *E′* on this line from the line of sight to locate a point on the deck. Construct the deck circle normal to the reference line.

Locate the mast, which is the pole of the deck circle. Construct a mast-bow circle that makes angle *A′* with

more on page 64

Figure 9

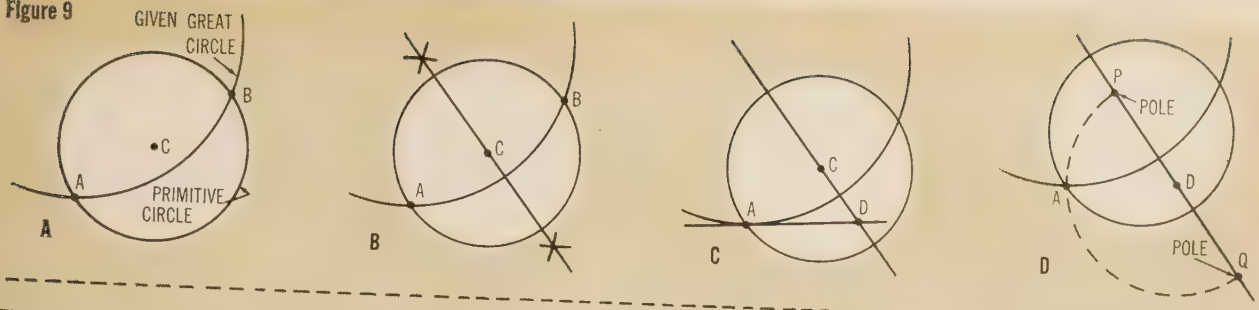


Figure 10

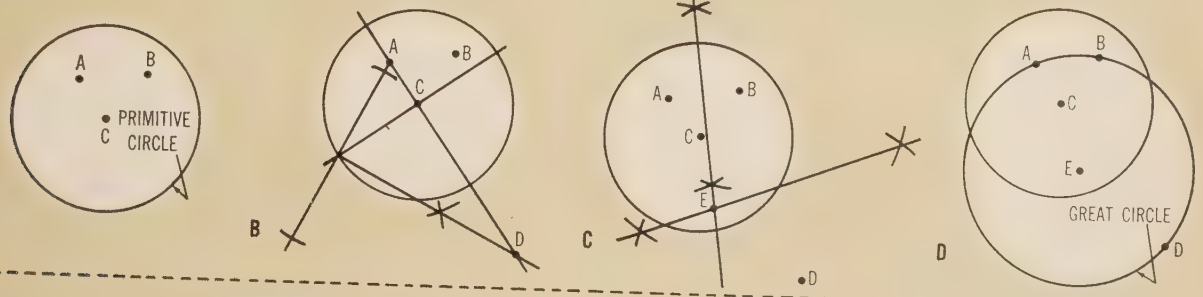


Figure 11

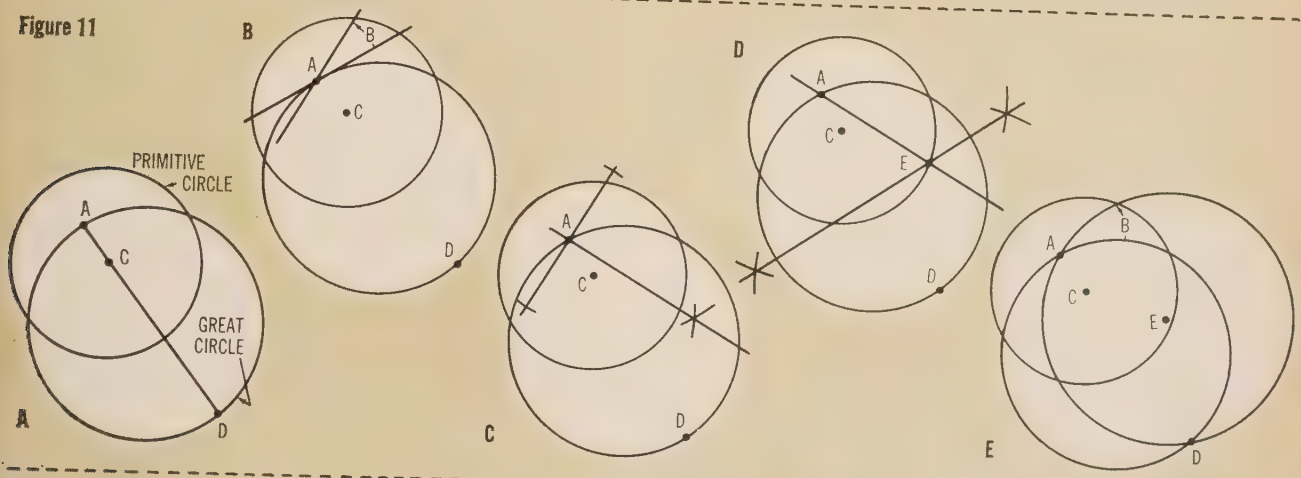
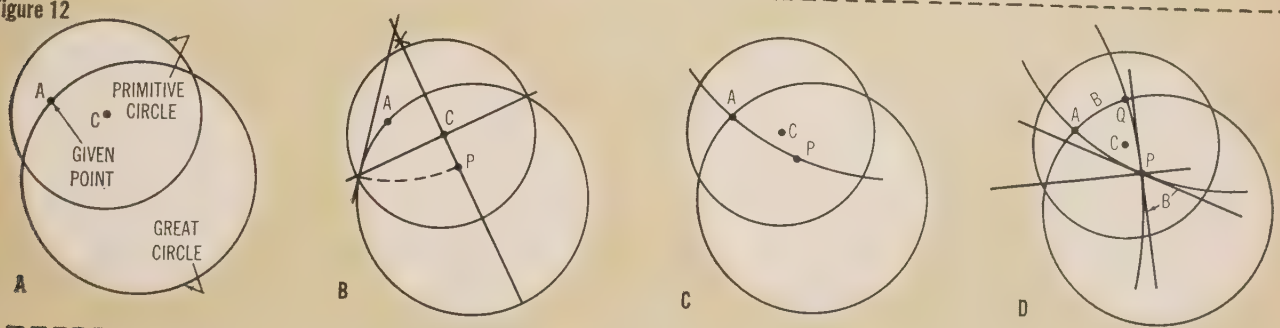
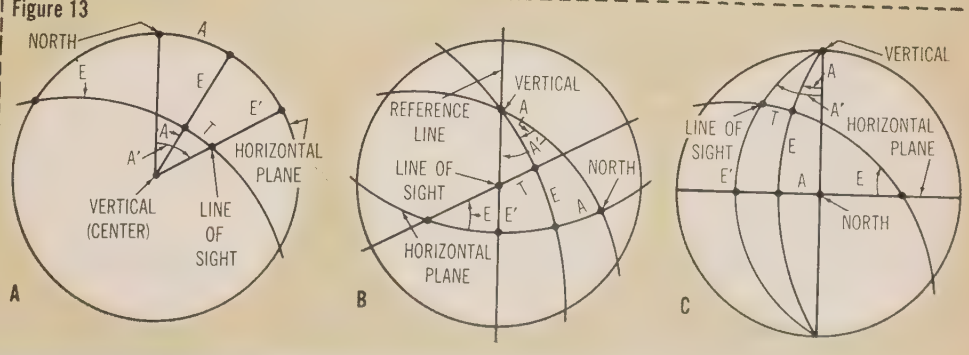


Figure 12



CONSTRUCTIONS of two poles of a given great circle, of a great circle through two given points and another making a given angle at a given intersection, and of a given arc length from a given point; three aspects of a three- and two-axis mount problem.

Figure 13



the reference line at the mast. Construct a circle that makes angle A with the mast-bow circle at the mast.

Draw a radial line through the line of sight and the intersection of the last circle with the deck. Construct a circle normal to the last line at the intersection with the deck.

Typical shipboard problem solved

Figure 15 shows a typical shipboard problem involving the relationship of pitch and roll and level and cross-level angles, where P is the pitch of the ship; R, roll; B, relative bearing (in the true horizontal plane); B', train angle (in the deck plane); L, level angle; and Z, cross-level angle:

- To construct *Figure 15-A*, draw a reference line through vertical and heading. Lay off P along this line from the intersection with the primitive circle to locate the bow. Construct a circle normal to the reference line at the bow. Construct another circle making angle R with the first circle at the bow.

Lay off B from the reference line and draw a corresponding radial line. Construct a circle normal to this line at the intersection with the deck.

- To construct *Figure 15-B*, draw in diameters normal to each other to represent the vertical-heading and horizontal planes. Construct a circle making angle P with the horizontal plane at the intersection with the primitive circle. The intersection of this circle with the vertical-heading line is the bow.

Construct a deck circle making angle R with the first circle at the bow. Construct another circle making angle B with the vertical-heading line at the vertical point. Construct a circle normal to this circle at the intersection with the deck.

Earth is used as reference frame

Finally, take a problem typical of a class involving angular quantities for which the earth itself is the reference frame—find the relationship between the latitude and longitude of a satellite in orbit and the parameters of the orbit, where I is orbit inclination; A, true anomaly of the present position of the satellite; L, latitude of the satellite; U, relative longitude of the satellite with respect to the node; and H, angle between meridional plane and plane of orbit (*Fig. 16*):

- To construct *Figure 16-A*, draw in diameters normal to each other to represent equator and nodal meridian. Lay off I from the equator at the center and draw a line representing the orbital plane.

Lay off A along the orbit from the node to locate the present position point. Construct a circle through north pole and present position.

- To construct *Figure 16-B*, draw a reference line through the north pole to represent the nodal meridian. Construct an orbit circle making angle I with the primitive circle at the node.

Lay off A along the orbit from the node to locate the present-position point. Draw a radial line through north pole and present position.

- To construct *Figure 16-C*, draw a reference line through the present position. This line contains the north pole. Lay off L along this line from the present position to locate a point on the equator. Construct the equator circle normal to the reference line.

Locate the north pole, which is the pole of the equator. Construct the nodal-meridian circle making angle U with the reference line at the north pole. The intersection of this circle with the equator is the node. Draw a radial line through node and present position.

By now, you should be able to manipulate angles, choose the projection aspect (or succession of aspects) best suited to solve any particular problem, and construct the necessary diagrams freehand. However, you still have to learn how to use the most valuable tool provided by stereographic projection: the solution of vector problems.

Vector direction in three-dimensional space may be represented by a point on a stereographic projection. You are limited to direction only and cannot show magnitude. However, you can use mathematical calculations based on stereographic projection to solve any vector problem.

Once you know the direction and magnitude of any given vector, you can calculate the component of that vector along any other specified direction: it equals the magnitude of the given vector multiplied by the cosine of the angle between this vector and the specified direction.

Specified direction shown as point

In stereographic projection, any specified direction—including that of any vector—is represented by a point. The projection makes it easy to visualize the angle between any two directions. Complicated problems can be simplified by multiple resolutions of vectors.

Many problems in stabilization and navigation systems involve the angular velocity of rotating bodies. Vectors are used to represent these velocities. A typical stereographic projection in this case (*Fig. 17*) might show the three principal axes (*1, 2, 3*) of a vehicle in relation to an inertial reference frame.

The primitive circle and two diameters define the principal planes of the inertial system. The yaw, pitch, and roll angles (Y, P, R) are applied as rotations about points *4, 5,* and *1*, respectively, so that the inertial reference frame is rotated into the vehicle axes *1, 2,* and *3*.

Now assume that Y, P, and R are changing with time and that their respective rates are $\dot{Y}$, $\dot{P}$, and $\dot{R}$. The directions of these angular rate vectors are represented by points at the vertices of the respective angles. By convention, a positive angular velocity at a given point in the projection represents an angle increasing in the counterclockwise direction.

Total angular velocity is wanted

Now suppose you want to determine the components (along the vehicle axes) of the vector representing the total angular velocity of the vehicle. The vehicle axes are in the direction of the nose (point *1*), of the right wing (point *2*), and downward (point *3*). You start with the original vectors $\dot{Y}$, $\dot{P}$, and $\dot{R}$, and, through successive resolutions, find the components in the desired directions *1, 2,* and *3*.

Let W be the total angular velocity and use subscripts to denote directions along different axes. You can then write the general relation as:

$$W_n = \dot{Y}_n + \dot{P}_n + \dot{R}_n.$$

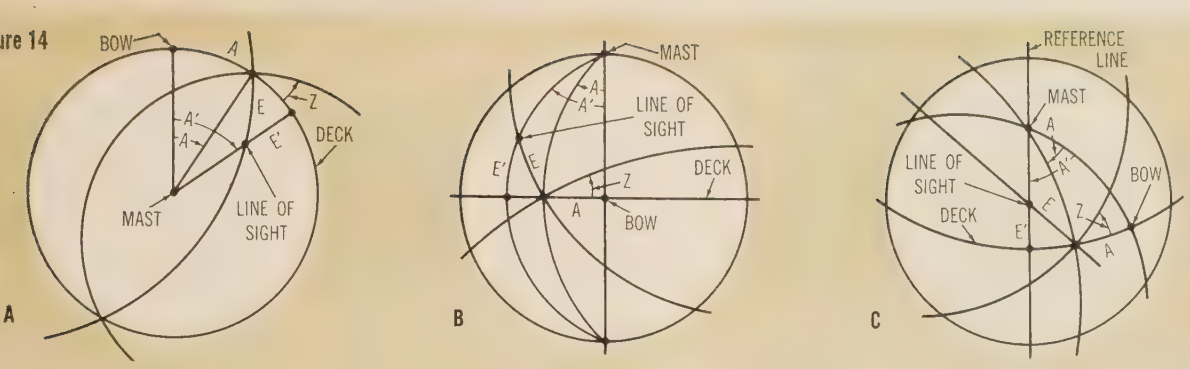
Since *4, 5,* and *1* are the specified directions of $\dot{Y}$, $\dot{P}$, and $\dot{R}$, respectively, you can write:

$$\dot{Y}_4 = \dot{Y},\ \dot{P}_5 = \dot{P},\ \dot{R}_1 = \dot{R}.$$

Applying the law of cosines, you also get:

$$\dot{Y}_6 = \dot{Y}_4 \cos P = \dot{Y} \cos P,$$

Figure 14



THREE aspects of a shipboard mount problem; two aspects of a shipboard stabilization platform problem; three aspects of a satellite orbit problem; typical stereographic representation of angular rates in vector form

Figure 15

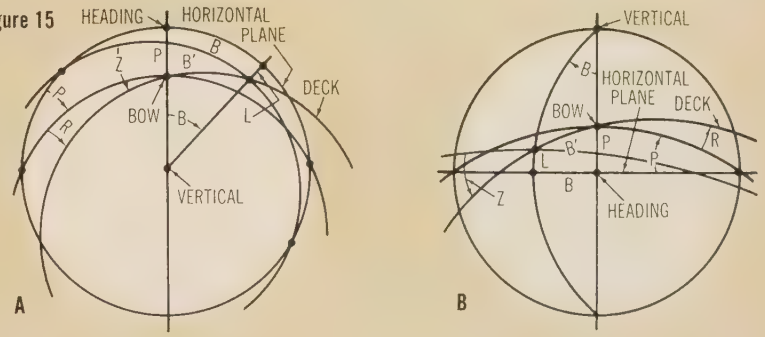


Figure 16

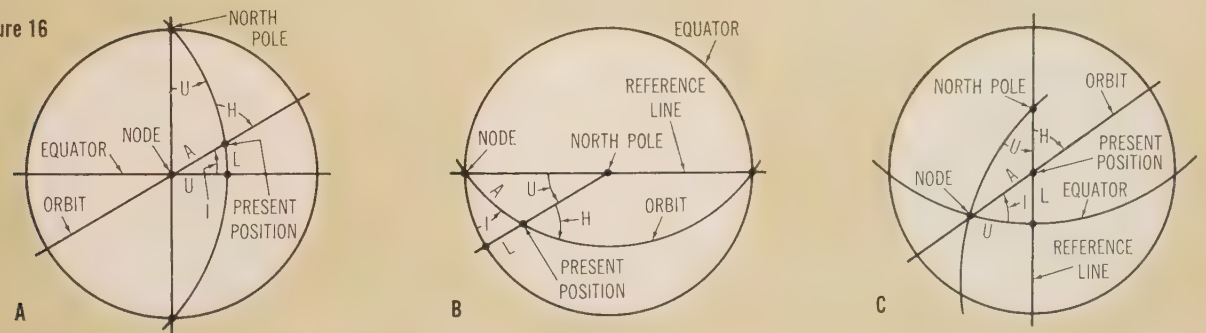
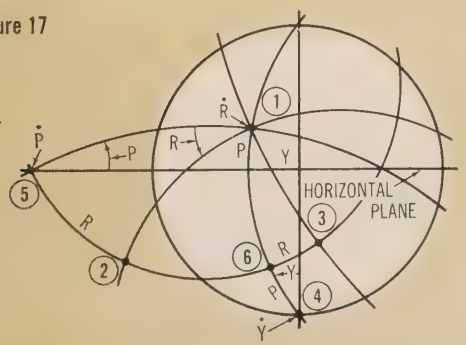


Figure 17



Reprints of the articles on stereographic projection (including next month's article) will be available in limited quantities to fill single-copy and small-lot orders. For bulk orders, prices will be quoted. In either case, please address

Reprint Dept.,
SPACE/AERONAUTICS,
205 E. 42nd St., New York 17, N. Y.

Reprint requests probably will be filled in August.

$$\dot{Y}_1 = \dot{Y}_4 \cos(90° + P) = -\dot{Y} \sin P.$$

Since *1*, *5*, and *6* are all 90 deg apart, $\dot{P}_1$, $\dot{P}_6$, $\dot{R}_5$ and $\dot{R}_6$ are all equal to zero. Also, since *4* and *5* are 90 deg apart, $\dot{Y}_5$ equals zero. We now get:

$$W_1 = -\dot{Y} \sin P + \dot{R}, \; W_5 = \dot{P}, \; W_6 = \dot{Y} \cos P.$$

Resolving *5* and *6* into the *2* and *3* directions gives you:

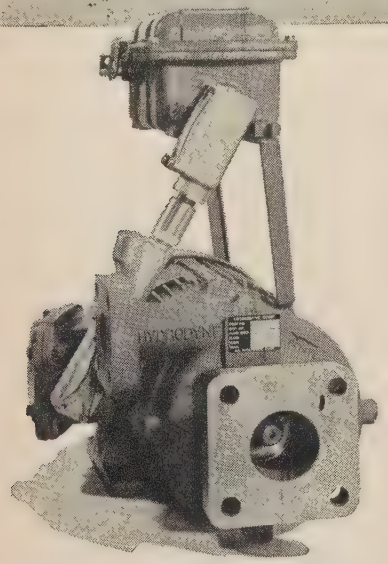
$$W_2 = W_5 \cos R + W_6 \cos(90° - R) = \dot{P} \cos R + Y \cos P \sin R, \; W_3 = W_5 \cos(90° + R) + W_6 \cos R$$

$$= \dot{P} \sin R + Y \cos P \cos R,$$

and the desired components are all found.

You may have noticed that the order of resolutions follows a pattern. Each successive resolution produces an orthogonal set of component directions—the three axes all remain 90 deg from each other. Two components are always resolved into a new set of directions without disturbing the value of the third component or being affected by this value.—End

an EFFICIENT HYDRODYNE PUMP for CRYOGENY



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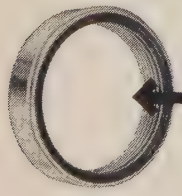

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Aircraft and Missile Design and Maintenance Handbook, by C. A. Overbey. This is intended primarily as a practical handbook for maintenance engineers, mechanics and specialists at repair and modification centers. However, since it contains much tabular data on such topics as standard fittings, fasteners, electrical symbols, etc., it may also be of interest to designers. The Macmillan Co., 60 Fifth Ave., New York 11, N.Y., $9.75.

Fundamentals of Stress Analysis, Second Edition, by A. Deyarmond and A. Arslan. The new edition of this book, in addition to covering the classical beginning phases of stress analysis, includes new material on such subjects as missile shell analysis. Many reference formulae, tables and graphs are given in the appendix. Aero Publishers, Inc., 2162 Sunset Blvd., Los Angeles 26, Calif. $5.75.

The Aerodynamics of Powered Flight, by R. L. Carroll. Aim of this text is to take a new approach to the subject by using the rocket as an introduction to aerodynamics. In the book, the concept of lift has been based on the analysis of rocket thrust. Besides fluid flow and airfoil theory, other topics covered include fundamentals of propulsion, stability, performance, design and control. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N.Y. $8.50.

Artificial Earth Satellites, Volume I and II, edited by L. V. Kurnosova. This translation presents revised texts of reports by Russian scientists on the results of their first three satellites. The reports were given at the Fifth Assembly of the Special IGY Committee in Moscow, August '58 and include data on the dog Laika. Other subjects covered include cosmic ray measurements, density of the upper atmosphere, electron density distribution and use of the Doppler effect for finding orbit parameters. Plenum Press, 227 W. 17th St., New York 11, N.Y. $9.50.

Air Aces of the 1914-18 World War, edited by Bruce Robertson. Biographies of air aces of eight countries on both sides are given, including records and descriptions of aircraft. Aero Publishers, Inc., 2162 Sunset Blvd., Los Angeles 26, Calif. $8.50.

Mechanical Properties of Intermetallic Compounds, edited by J. H. Westbrook. The proceedings of a special symposium held in Phila., Pa., in May, '59, by the Electrochemical Society are given here. Examples of subjects discussed include Transition Element Beryllides; Electromechanical Properties of InSb; NiAl and Ni_3Al studies, etc. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N.Y. $9.50.

Rocket Propellant Handbook, by B. Kit and D. S. Evered. Nearly 100 chemicals, including fuels, oxidizers and monopropellants, are described. Each entry has tables of heat value, density, etc., plus discussion of storability, handling requirements and performance with other materials. The Macmillan Co., 60 Fifth Ave., New York 11, N.Y. $12.50.

The Internal Combustion Engine in Theory and Practice, by C. F. Taylor (Vol. I). Co-published with the Technology Press of MIT, the first of this two volume series covers thermodynamics, fluid flow and performance. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N.Y. $16.

Cemented Carbides, by Dr. P. Schwarzkopf & Dr. R. Kieffer. Most of the text of this book deals with the composition and properties of specific compositions of pure refractory material and binder metal of high ductility. Also included is a chapter on recently developed ceramic (oxide) tool materials. Also discussed are commercial applications of cemented carbides. The Macmillan Co., 60 Fifth Ave., New York 11, N.Y. $15.

Guide to the Space Age, by C. W. Besserer & H. C. Besserer. Over 5000 words and phrases common to present day aerospace technology are defined in this book which is written mainly for the layman. Prentice-Hall, Inc., Englewood Cliffs, N.J. $7.95.

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From the historic moment in 1942 when twin General Electric I-A engines powered the first jet flight in America, G-E engines have logged 27 million jet flight hours. And, G-E jets like the J33, J35, J47, T58, J85, J79, and CJ-805 have consistently set new standards of performance and reliability.

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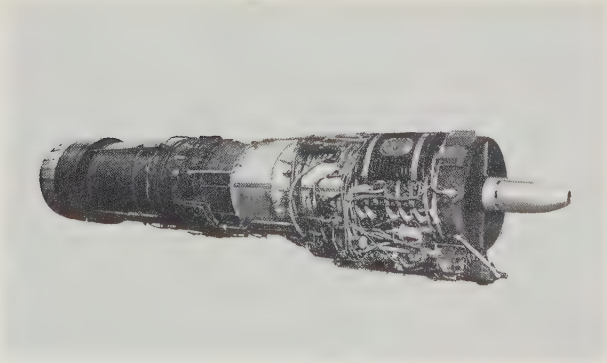
For almost two decades jet thrust has been increasing rapidly. G.E. has helped lead the way. Each new G-E engine has added to a remarkable record of reliability. Today, the J79-powered Lockheed F-104 has established an outstanding in-commission rate with USAF.

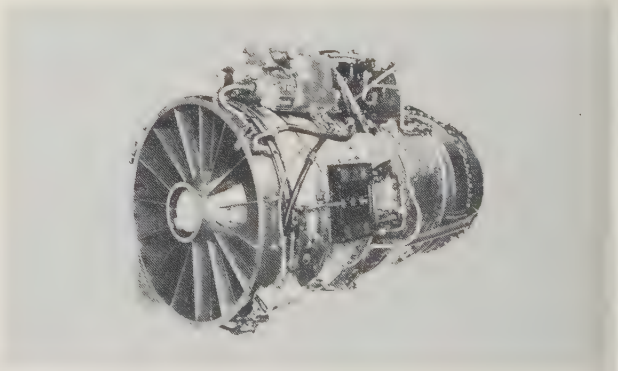
Sea forces will soon be strengthened by the McDonnell F4H and the North American A3J—the fastest, highest-flying aircraft in Navy history.

USAF's fastest, highest-flying bomber, Convair's B-58, is J79-powered. And, USAF's J79-powered Lockheed F-104 has held simultaneously the world's speed, altitude, and time-to-climb records—an unprecedented triple crown.

At the other end of the flight propulsion spectrum, G-E small gas turbines will soon enter operational service with the Air Force and Navy. The Navy's newest ASW and utility helicopters will be powered by the T58, which has demonstrated its reliability in thousands of demanding test hours.

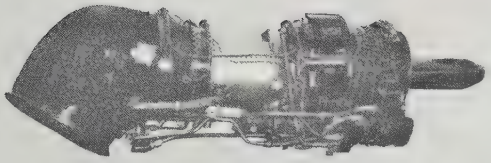
The high performance J85 turbojet will soon enter USAF service powering McDonnell's GAM-72 decoy missile and Northrop's T-38 jet trainer.

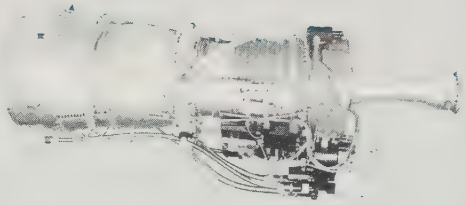




J79 After more than three years of production, G.E.'s J79 remains the most advanced U.S. production turbojet. The record-breaking J79 provides more than 15,000 pounds of thrust, yet some models weigh as little as 3200 pounds. J79-powered aircraft have logged considerably more than half the world's Mach 2 time. Six Mach 2 air weapons are J79-powered: McDonnell F4H Phantom II, North American A3J Vigilante, Convair B-58 Hustler, Lockheed F-104 Starfighter (all pictured in main illustration), Grumman F11F-1F Super Tiger, and Chance Vought Regulus II missile.

J85 Advanced aerodynamic and mechanical design make G.E.'s J85 turbojet the highest thrust-to-weight ratio powerplant in its class. Weighing just 525 pounds and delivering 3850 pounds thrust, the reheat J85-5 powers Northrop's T-38 Talon supersonic trainer (pictured in main illustration) and N-156F Freedom Fighter (right). Another J85 version (above), which weighs 325 pounds and produces 2450 pounds thrust, is in production for the McDonnell GAM-72 decoy missile (right).





T58 The T58 brings important benefits to helicopters —increased payloads or range, faster cruising speeds, greater endurance. Engines shipped have averaged significantly better than guarantees of 1050 shp, 0.64 SFC, and 271-pound weight. A 1250 shp growth version enters production this year. T58 has been flight tested in single and twin engine helicopters including Sikorsky's HSS-1F, HSS-2 (left), and S-62; Kaman's HU2K (left); and Vertol's YHC-1A and H-21D.

T64 Low SFC and attractive power-to-weight ratio make G.E.'s versatile T64 turboprop/turboshaft ideally suited for a variety of aircraft. Among them: helicopters and fixed wing designs (right), skycranes, new VTOL/STOL designs. Turboprop configurations, with gearbox above or below centerline, deliver 2570 eshp at .522 ESFC. Turboshaft versions produce 2650 shp at .506 SFC. All models have common power sections, differ only in gearing and accessories.

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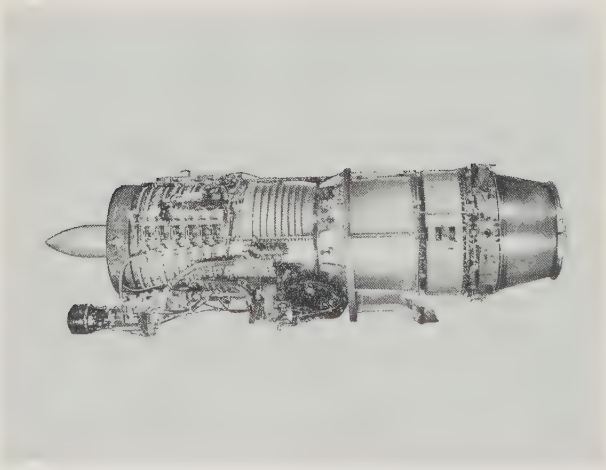
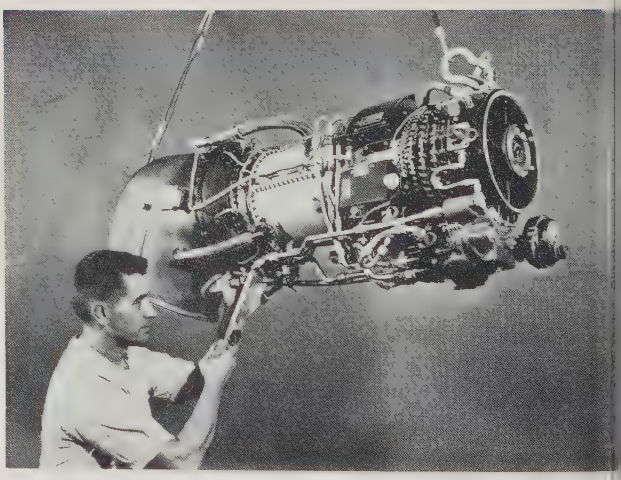


CJ-805-3 G.E.'s first commercial engine, the CJ-805-3, enters airline service this spring. It will provide the power to carry passengers in Convair 880 jetliners at 615 miles per hour. The CJ-805 weighs 2800 pounds, delivers more than 11,000 pounds of thrust. It is 110 inches long, 32 inches in diameter.



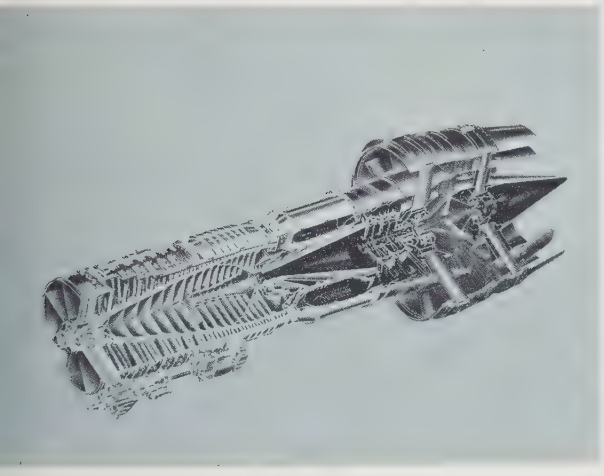
CT58 The CT58 is the first U.S. turboshaft to be FAA-certificated. It will power the twin-turbine Sikorsky S-61 and Vertol 107 (both in main illustration above) which begin passenger service next year. Sikorsky's CT58-powered single-engine S-62 is being offered to helicopter operators and corporations.

GENERAL ELECTRIC

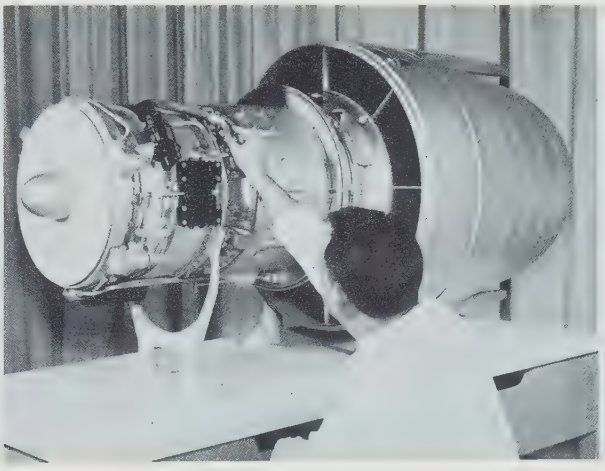
G-E engines will be the most thoroughly tested yet to enter airline service. For example, General Electric's CJ-805-3 flight test program was the first of its kind ever undertaken by a U.S. manufacturer at his own expense to test a commercial turbojet under flight conditions. The CJ-805 powered Convair 880 (top) has exceeded all of its performance guarantees and performed reliably in flight test. Delta Air Lines' first Convair 880 established speed records on its maiden coast-to-coast flight.

Jetliners powered by CJ-805-3 or -23 engines have been ordered by American Airlines, Avensa (Venezuela), Capital Airlines, Civil Air Transport (Formosa), Delta Air Lines, REAL (Brazil), Scandinavian Airlines System, Swissair, and Trans World Airlines.

At the other end of the power spectrum: America's first turbine-powered helicopters, already on order by Los Angeles Airways, Chicago Helicopter Airways, and New York Airways, will be powered by G-E CT58 engines. Next natural step: turbinization of helicopters and transports owned and operated by industry.



CJ-805-23 General Electric is flight testing its leased B-66 with aft-fan CJ-805-23 engines. When tests began, it marked the first time an engine manufacturer had test flown a turbofan engine as the primary powerplant of an aircraft. The twin aft-fan engines are performing reliably—proving themselves prior to airline service. CJ-805-23 engines will power the Caravelle VII and Convair 600.



CF700 Compared to turbojets in its class, the CF700 turbofan will provide higher thrust per dollar, greater range, shorter take-off, and less noise. The CF700 will combine the proven J85 gas generator and a scaled-down version of the CJ-805-23 aft-fan to produce 4000 pounds sea level thrust at 0.69 SFC. Flight-worthy CF700's are scheduled for April, 1961, with FAA-certificated engines available in February, 1962.

27 million jet flight hours mean

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Twenty-seven million jet flight hours form a solid foundation upon which General Electric research and development can build to meet the needs of the near and distant future.

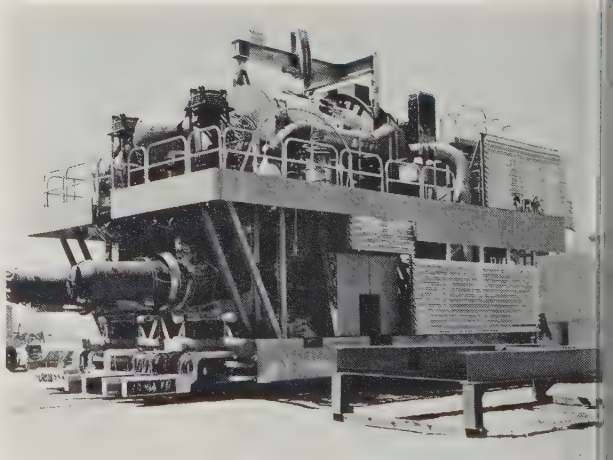
The Mach 3 North American B-70 Valkyrie bomber, for example, represents the next stride forward for manned aircraft. G.E. is developing the highly advanced J93 engines which will power it.

General Electric, under contract with USAF and the AEC, is developing a nuclear propulsion system for America's first nuclear-powered aircraft, as revolutionary as the B-70.

In rocket, VTOL, and space power and propulsion, systems now being investigated at General Electric will help make propulsion progress.

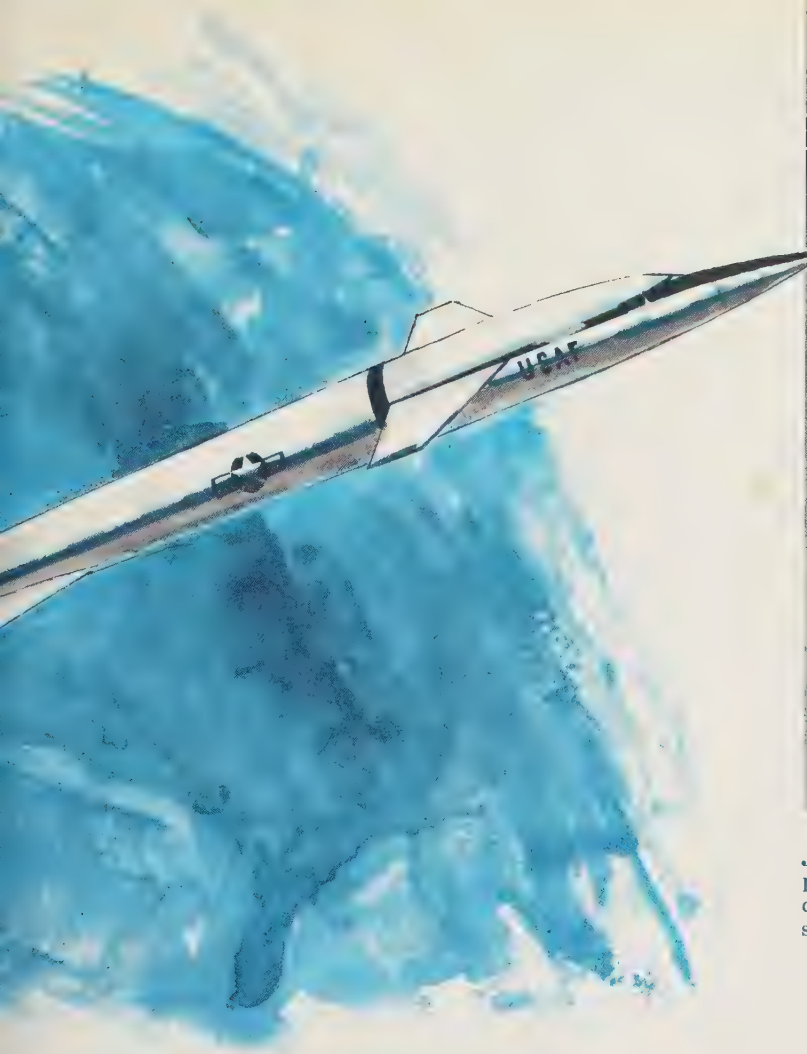
To achieve the challenging objectives of the present and the future, G.E. applies its knowledge and experience, and marshals R&D facilities among the most complete in the nation.

G.E.'s more than 100 research laboratories strive for new basic knowledge which can be applied to aerospace progress. For example, at the pioneering General Electric Research Laboratory, basic research is leading to advances in metallurgy, cryogenics, and other sciences vital to aerospace progress. These activities supplement the direct efforts of extensive aircraft gas turbine R&D facilities at Evendale, Ohio, and Lynn, Massachusetts.

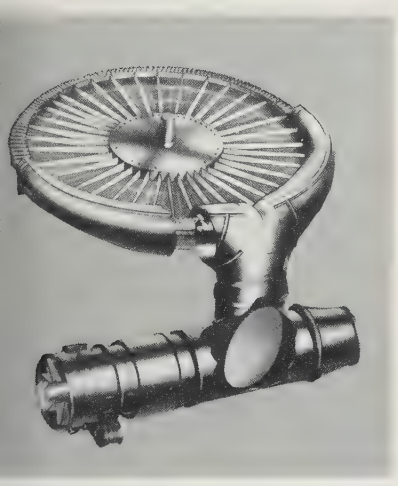


NUCLEAR PROPULSION

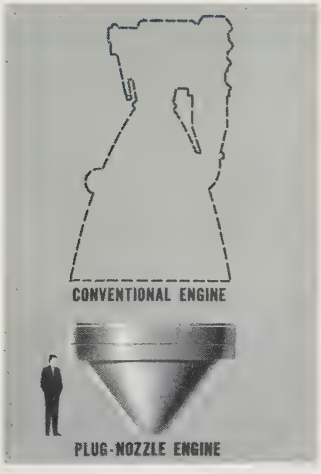
This special test assembly was designed and built b General Electric under contract. It consists of a nuclea reactor, shield, controls, and two modified J47 engines General Electric first successfully operated a turboje on nuclear power in 1956. Development progress continuing.



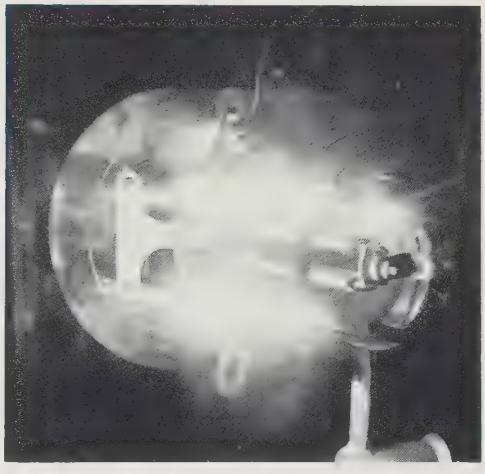
J93 The General Electric Mach 3 J93 will power the North American B-70 Valkyrie to cruising altitudes above 70,000 feet and speeds of more than 2000 mph.



'OMORROW'S VTOL
urrently under development, General lectric lift fan engines hold promise r a new generation of aircraft which n take off straight up, hover, and ove forward at high speeds.



ROCKET POWER
Development concepts at G.E. include plug nozzle engines (below) which are markedly smaller than conventional engines of the same thrust.

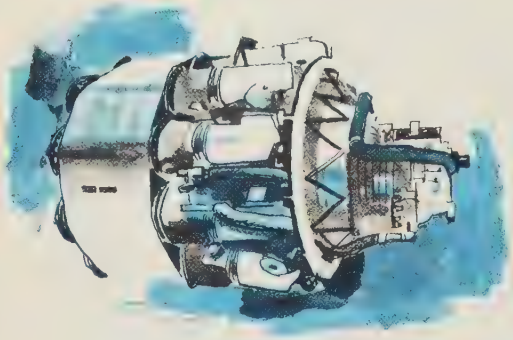


ION ENGINES
In the void of space, a few ounces of thrust can control vehicle flight paths. One way to achieve this thrust: electrical propulsion. G.E. is investigating an ion engine which electrostatically accelerates mass, such as cesium ions, to produce thrust.

GENERAL ELECTRIC

Milestones

in General Electric's 27 million jet flight hours



In 1942, the first jet flight in America was General Electric powered. Twin I-A engines (above) powered the Bell P-59 at 450 mph.

The J47 powers Boeing B-47 Stratojet bombers, backbone o America's deterrent strength during the past decade.

North American's F-86 Sabre Jets, powered by General Electric J47's, scored a 14-1 victory ratio in Korea.

America's first Mach 2 engine, the J79, won accolades f performance and reliability. Vice President Nixon (cente presented the Collier Trophy to (left to right) USAF pilo Major Walter Irwin and Lt. Col. Howard Johnson, G.E Gerhard Neumann and Neil Burgess, Lockheed's Claren Johnson for F-104/J79 design and flight. (186-

GENERAL ELECTRIC ENGINES POWERING THESE AIRCRAFT HAVE FLOWN MORE THAN 27 MILLION JET FLIGHT HOUR

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CONVAIR 880
CONVAIR XB-46
CONVAIR XP-81
DOUGLAS RB-66A
DOUGLAS XA-26F
DOUGLAS XB-43A
DOUGLAS XB-53
DOUGLAS XF4D
DOUGLAS D-558
GRUMMAN F11F-1F
KAMAN HU2K
LOCKHEED P-80
LOCKHEED F-104
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MARTIN XB-51
McDONNELL F4H-1
McDONNELL GAM-72
NORTH AMERICAN B-45
NORTH AMERICAN F-86
NORTH AMERICAN F-86D
NORTH AMERICAN F-86H
NORTH AMERICAN XFJ-1
NORTH AMERICAN FJ-2
NORTH AMERICAN A3J-1
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NORTHROP N-156 F
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NORTHROP XF-89
NORTHROP YB-49
REPUBLIC XP-84
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FLIGHT PROPULSION DIVISION

GENERAL ELECTRIC

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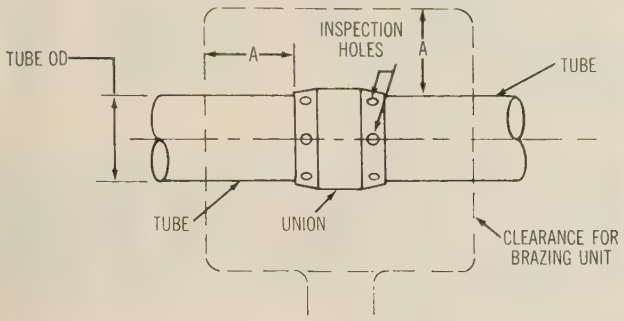

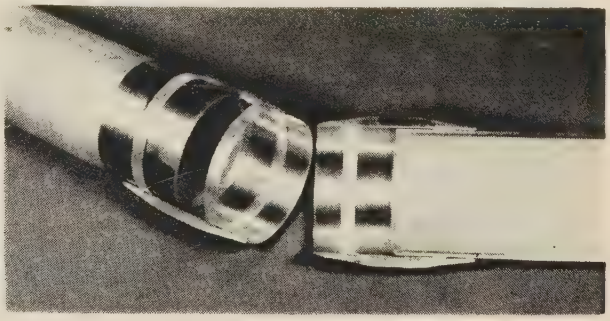

FIGURE 1: Typical B-70 hydraulic coupling (left) and cutaways showing how the braze alloy ring is preplaced between sleeve and tubing (on designs without inspection holes). Minimum clearance for the brazing unit (A) is 5/8 in. for tube ODs of 1/4-5/8 in., 3/4 in. for 3/4-in. ODs, 7/8 in. for 7/8-in. ODs, and one inch for ODs from one to 1 3/4 in.

Brazed joints, thin-wall tubing streamline B-70 plumbing

The rigorous performance demands of advanced vehicles like the B-70 call for unconventional design approaches. An old-style hydraulic system for the B-70, for instance, would simply have weighed too much. By going to brazed fittings and thin-wall tubing, NAA cut the system weight by 40-60 per cent.

THERE never was a day in aircraft design when any pound saved wasn't worth its weight in gold. Today, though, this pound is worth its weight in diamonds, you might say—certainly when it comes of advanced designs like USAF's Mach 3 B-70 bomber. As engineers at North American Aviation, Inc., International Airport, Los Angeles 45, Calif., told SPACE/AERONAUTICS, just 0.001 in. over tolerance on honeycomb face sheet means a ton of extra weight on the B-70.

Weight reduction was particularly emphasized in the plane's plumbing. The hydraulic system has to withstand pressures of 4000 psi and temperatures of up to 630 deg F. After a series of tests, NAA decided that it had to use AM 350 CRT steel tubing. Assembled with AN or MS standard fittings, these lines would impose a weight penalty. In any case, neither AN or MS standard fittings can be used at the B-70 lines' pressures.

NAA concluded that a new method of tube joining was required. The method it finally chose relies on specially designed unions to form induction-brazed joints. In the hydraulic system alone, it provides a weight saving of 25-30 per cent in fittings. It also enabled use of high strength thin-wall tubing instead of the old type of heavy wall, which brought the overall weight saving to 40-60 per cent.

Figure 1 shows the hydraulic joint design. The union is made from machined AM 355 CRES (corrosion-resistant bar). It has inspection holes, with the braze alloy forming a fillet at the inner side of the holes. The fit-up of the union limits the flow of the braze alloy, and the inspection holes permit visual joint checking. This approach was also used on the fuel and environmental lines.

Pre-placed braze alloy in the form of foil is snapped into place in recesses inside the union. Diametrical clearances of 0.002-0.008 in. between union and tubing were found to give satisfactory results.

more on page 78

NEW DIGITAL TELEMETRY DECOMMUTATOR

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For digital outputs, accuracy is 10 bits, 0.1%, at sampling rates up to 1150 pps and 8 bits, 0.4%, at higher rates, or 8 bits over the entire range.

Modular, computer-type construction has front-panel test points and built-in meters for rapid maintenance. Transistorization is responsible for the unusually low power consumption and basic ruggedness of the unit.

Condensed Specifications

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PATCHING: Plug-in type allows connection of any output to any input, cross-strapping of any channels, reference channels anywhere in frame.

LINEARITY: ±0.04% of best straight line.

REFERENCE CORRECTION: Reference changes of ±20% corrected to within 0.1% f.s. (10-bit output) or 0.4% f.s. (8-bit output); manual or automatic.

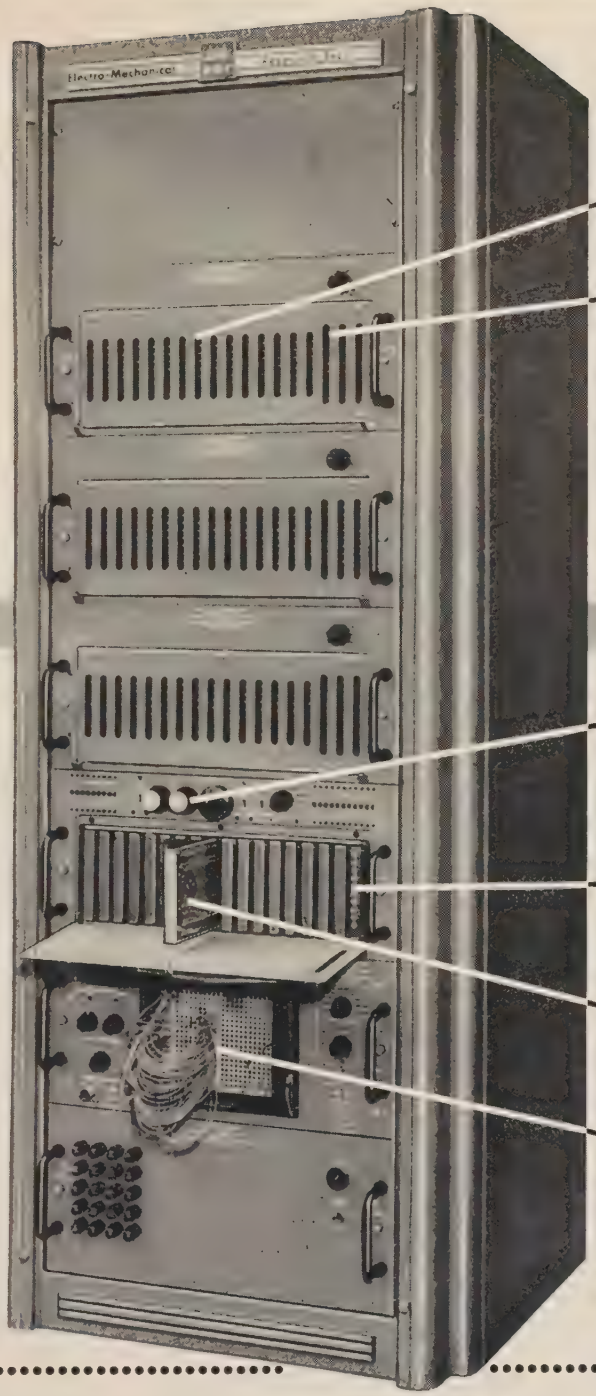
STABILITY: Closed loop, 0.05% for any period of time; no warm up.

STORAGE DECAY: None.

DIGITAL OUTPUTS: Parallel binary, 10 bits; BCD, 3x4 bits; 10V p-p; rise time 2 μ s; impedance 2K single ended.

ANALOG OUTPUTS: Std., ±2.5V into 4.7K; pen or film recorder drive available; instantaneous response to f.s. step change.

SIZE: 26¾″ x 19″ w. plus 8¾″ h. each for 16-output analog drawer; 16-output 8-bit binary drawer; PCM input drawer; or printer drive drawer.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See these ground stations in Booths N1, N2. National Telemetering Conference

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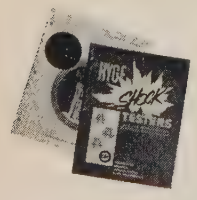

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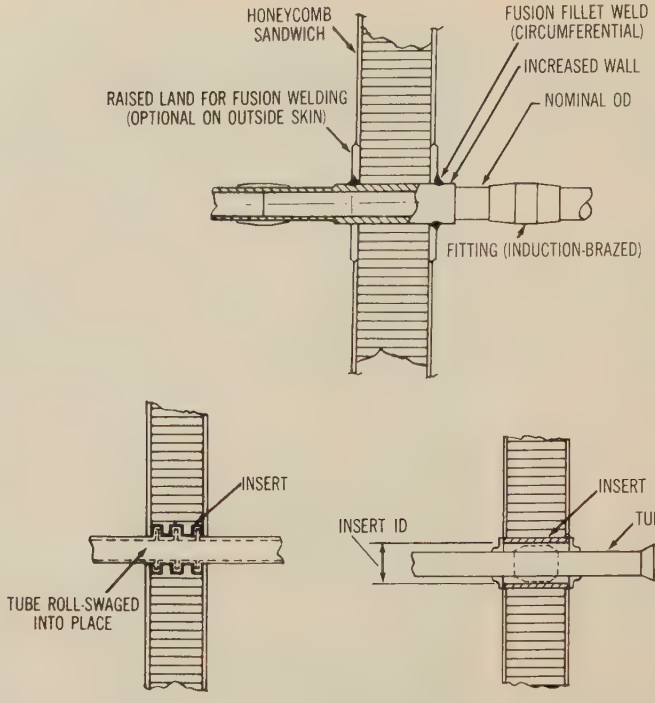

FIGURE 2: Development work is continuing on methods of routing B-70 tubing through honeycomb bulkheads. Fusion fillet welding (top) was one of the early proposals and is still under consideration. However, inserts brazed in place during bulkhead assembly now appear to be the more likely solution. The tube could then be brazed or welded to the insert (bottom left), for instance, or it could be roll-swaged into the insert (bottom right). Many other tube fitting installations are also under study at NAA.

The braze alloy is a eutectic composition of 71.8 per cent silver, 28 per cent copper, and 0.2 per cent lithium, which brazes without flux and makes it possible to use "in-place" brazing. (Other braze alloys are also being studied.)

For other types of joints—tee, cross, elbow sections, etc.—NAA uses a building block approach: the joint section is made from a piece of regular tubing to avoid the weight penalty.

In the case shown in *Figure 4*, the center opening in the tee is made, and the other portion of the tee is then automatically heliarc-welded to the opening. Elbows are made by forming under high pressure, with the tube pushed through a die, with back-up pressure to control the tube in the dies.

NAA engineers note that elsewhere than in the hydraulic system they can achieve even more impressive weight savings. One reason for this is that they can use thin-wall austenitic steels and so avoid the problem of annealing during the braze operation created by the PH steels.

For many of non-hydraulic lines, material with thicknesses of as little as 0.007 or 0.006 in. is used. To make it possible to handle these thicknesses in production, convolutions are added to stiffen the ducting. For one of the environmental lines, 0.003-in.-thick six-inch-diameter convoluted aluminum ducting is used for lengths of as much as 10-20 ft. In this case, about 10 convolutions per inch provided more than a hundred fold increase in stiffness, SPACE/AERONAUTICS was told.

Fillets at ends of unions are checked

Joints in these areas are also made by induction-brazing, but the unions are formed from tubing rather than bar (*Fig. 3*). For inspection, the fillets at the ends of the union are checked.

Many of the bulkheads in the B-70 are made of honeycomb. The bulkhead itself seals against about 45 psi, as against the hydraulic lines' 4000 psi. So it wasn't desirable to break the lines at the bulkhead. Instead, a hole is cut in the

more on page 80

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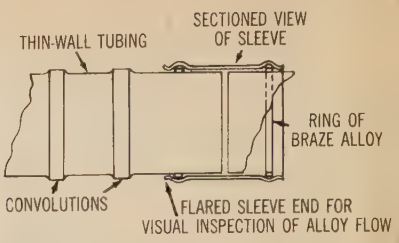

SECTIONED VIEW OF SLEEVE
THIN-WALL TUBING
RING OF BRAZE ALLOY
CONVOLUTIONS
FLARED SLEEVE END FOR VISUAL INSPECTION OF ALLOY FLOW

FIGURE 3: Typical joint design for B-70 fuel and environmental lines. The sleeve is made from tubing.

bulkhead, and an insert is installed with enough clearance for the standard coupling. The tube is then brought through and sealed to the insert by brazing, roll-swaging, welding, etc. (*Fig. 2*).

To make repairs, you can either melt the braze alloy and slip the sleeve to one side or cut the line and remove a section. NAA believes that in most cases the line will be cut. It has devised special cutters with which no chips will get into the line. To provide an added safeguard, methods of flushing out the cut tube with air, solvent, or possibly ultrasonically are being studied.

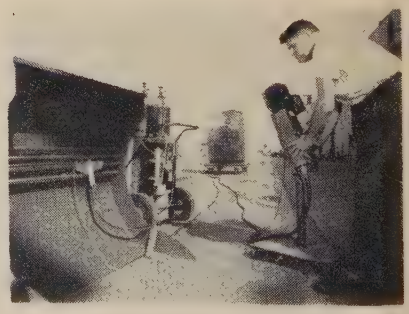
Several approaches open for repair

In repairs of the line, several approaches can be used. One would be to wrap the joint with a thin steel sheet and a layer of brazing alloy and then braze. Another would be to cut out a length of line and insert a new length and braze it in place with two standard couplings.

The key to the success of light,

more on page 82

REMOTE test operation of the induction braze unit 50 ft from the generator. The operator controls work with one of two remote control stations available with the Ther-monic generator unit.



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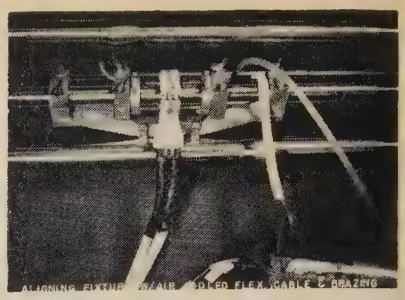


BRAZING work unit. An air-cooled, flexible with a three-turn, split work coil is used. Aligning fixture and glass purge shield are also shown.

high-strength tube joints was the development of methods for brazing tubing in place on the aircraft. In the past, it was necessary to take the work to the generator or vice versa. The solution, NAA decided, was to develop coax cables with a low impedance loss, so that a practical brazing fixture could be used at great distances from the generator.

Thin insulation cuts the impedance loss

One way to cut impedance loss is to use the thinnest possible insulation. NAA chose a triaxial coax using paper-thin irradiated polyethylene insulation. The two inner conductors are connected to form one conductor; the outer shielding is used as the other conductor. With two 50-ft cables in parallel hookup for the conductors, NAA states, the impedance is reduced. Tests show that this setup provides a small, flexible, dry, paralleled coax cable that—because of the low power loss—has a matching impedance to that of the RF output transformer of the generator.

The induction generator used so far is a portable Ther-monic Model C with a 15-kw output. It requires

more on page 86

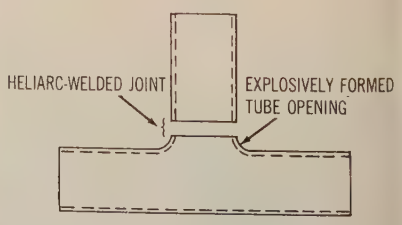
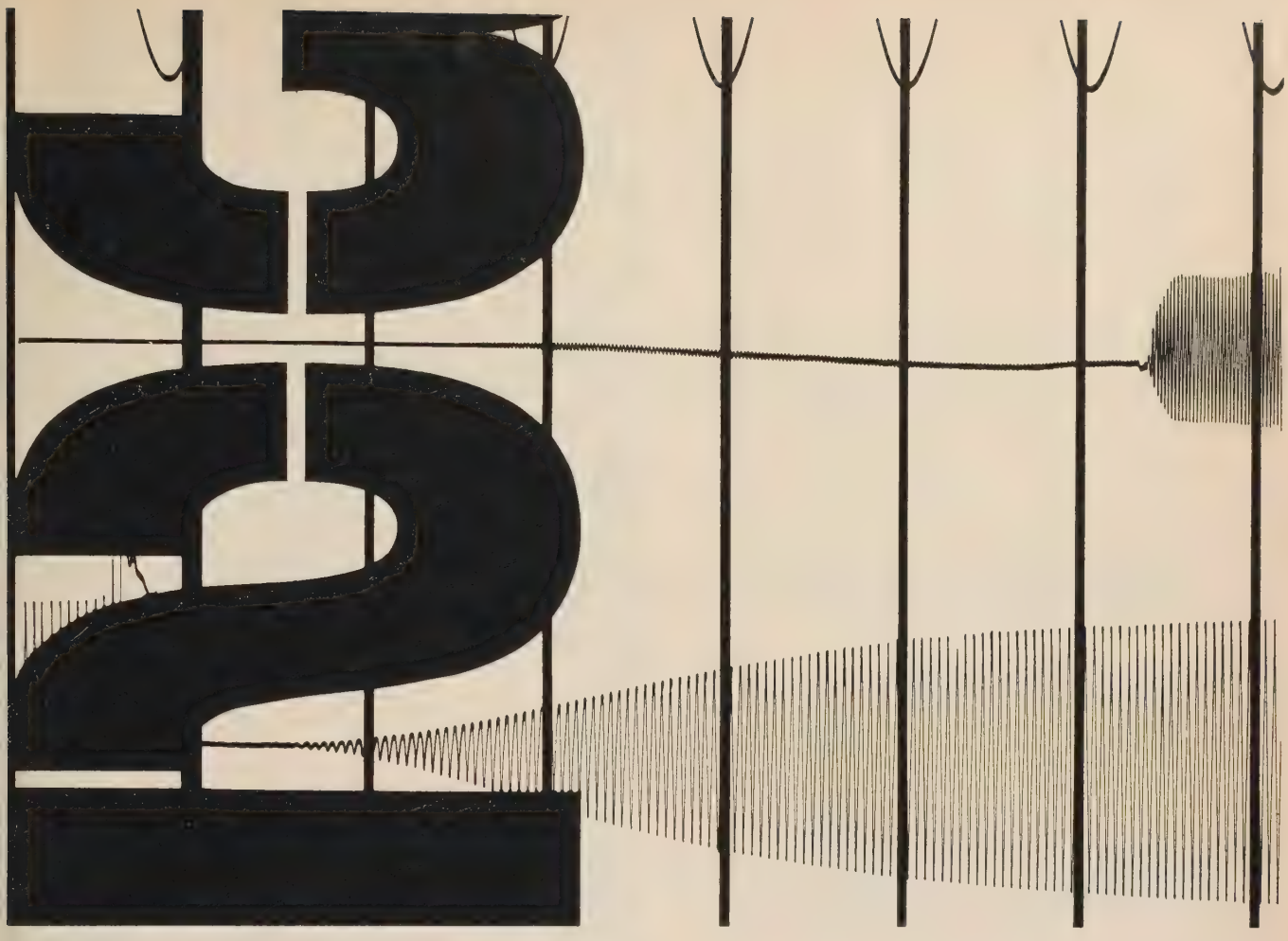


FIGURE 4: Fabrication of B-70 tee fittings. Cross fittings are made in similar fashion.



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through Chemistry

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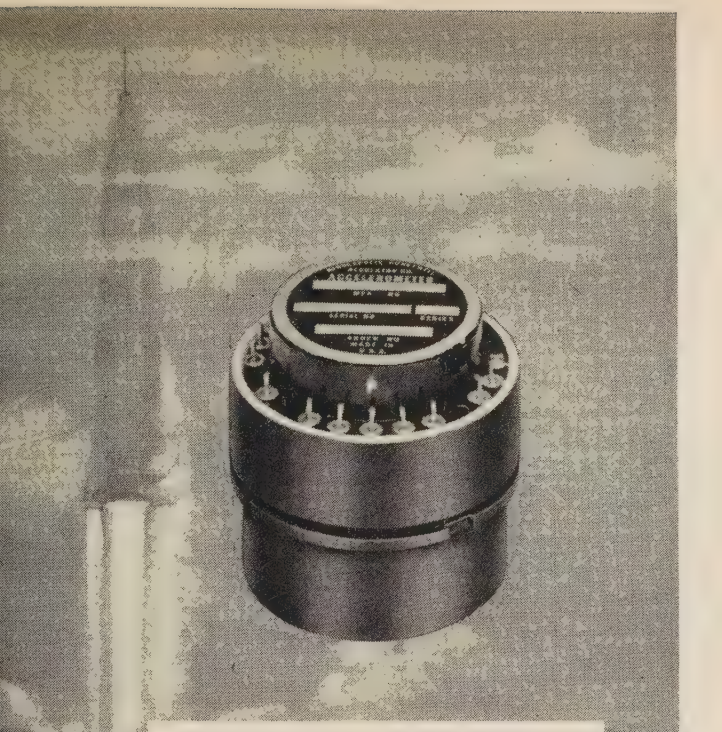
IN THE LAST FOUR YEARS:

Honeywell has produced more Precision Miniature Accelerometers...

---

and more Miniature Integrating Gyros than any other manufacturer!



GG56 ACCELEROMETER, typical of Honeywell's miniature pendulous line, is designed as a companion unit for the MIG gyro series below. The GG56 offers the advantages of few moving parts, high reliability and a life expectancy of 10,000 hours.

GG49 MIG, typical of Honeywell's Miniature Integrating Gyro line, combines small size and light weight with high accuracy. It is particularly applicable for use in central station instrument platforms and in short-time inertial and aided-inertial systems.

It's only natural that Honeywell, world's largest producer of gyros, should have produced more miniature integrating gyros and more precision miniature accelerometers in the last four years than any other manufacturer. But what does this mean to you, the customer? Just this: the experience Honeywell has gained in building over 30,000 floated gyros and over 18,000 accelerometers has been directly applied to our MIG line and our precision miniature accelerometers.

Although the GG49 Miniature Integrating Gyro was introduced by Honeywell four years ago, it has been continuously improved in accuracy and dimensional stability. New models have been added to meet various performance requirements so that Honeywell now has the most complete line of Miniature Integrating Gyros in the industry. These rugged MIGs are especially tailored to meet your requirements for advanced fire control systems, gyro reference systems, inertial navigation systems, radio-radar navigation systems, and missile tracking systems.

Honeywell precision miniature accelerometers also reflect Honeywell's gyro and accelerometer experience. Honeywell miniature accelerometers, precision-balanced to insure optimum reliability, are now available in angular, linear and integrating types.

Honeywell is eager to work closely with your systems engineers—incorporating gyros and accelerometers into your systems and developing modified or entirely new inertial components to meet your special needs. For further information, write Minneapolis-Honeywell, Dept. SE-5-110, 2600 Ridgway Road, Minneapolis 13, Minnesota.

Honeywell

H HONEYWELL *Military Products Group*

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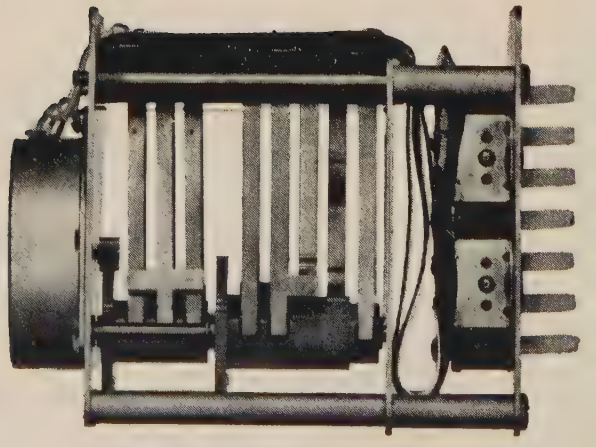
The A. W. Haydon Co. designed this series of repeat cycle timers for engineers with tricky timing problems and tight budgets. The low unit price on quantity runs will surprise you...and the savings we can offer on very large volume production sometimes surprises us! ■ Yet there has been no sacrifice in quality...it's all in the design. Special spring switches are supported in molded contact blocks; cams, cam followers and gears are molded nylon for long service life and extremely quiet operation. Two printed circuit cables supply internal wiring to 12 output circuits, and parallel cam shafts provide two cycling speeds. ■ The A. W. Haydon Co. has designed this repeat cycle timer to operate continuously for at least one year, but it will actually run for much longer. ■ The unit shown operates at 115V, 60 CPS, 2.5 watts power input. Its switch has been tested for 2 years (125 million cycles at 2 amps resistive 10VAC, 60 CPS) and is rated for 2.5 amp or a 7.0 amp inrush lamp load. ■ To be sure, other variations are available. A. W. Haydon will be delighted to quote these long life, low cost repeat cycle timers in any one of 125 standard speeds, 5 voltage ratings and 3 power supplies. All have Jones type terminal plugs for fast installation, and a quick-change motor mounting for ease of motor replacement. A clear plastic dust cover helps reduce noise level to a whisper. Write for information on your particular requirement.

LONG LIFE LOW COST REPEAT CYCLE TIMERS



THE AWH AYDON COMPANY
223 North Elm Street, Waterbury 20, Connecticut

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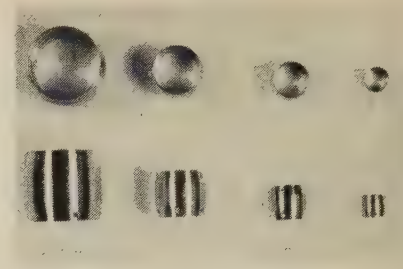

FOUR unions for brazing hydraulic lines. Their IDs are (l. to r.) 1½, 1, ¾, and ½ in.

one 440-V, three-phase, 60-cycle outlet and is divided into two compartments; oscillator section and high voltage rectifier and control section. It has two remote control stations to let the operator start the braze cycle near the work. The stations include a Microflex clock-type timer with time control from 1/10 to 120 seconds.

In preliminary brazing tests, expendable copper-wound, water-cooled work coils of various sizes were used. On the basis of these tests, production-type hinged, split coils were developed. However, NAA engineers say that the expendable coils are inexpensive and would be practical for use in "tight" areas.

The best results so far have been obtained with a three-turn, one-inch helical-split-type work coil. The conductors are imbedded in ceramic. The coil is cooled by plant air circulated through the coaxial coupling pins and then vented to the atmosphere. A purge jacket and a holding fixture are used with the unit. The coil's electric contacts are standard "cannon" pin-and-socket connectors machined to fit and brazed to the 3/16-in.-OD copper tubing that forms the loops of the coil. For large joints (up to 5-6 in.), a two-turn copper wound work coil has been used.

So far, pyrex purge gas shields have proved effective. The inert-gas atmosphere used around the joint that is being brazed is "special" bottled argon. (Regular bottled argon has a dew point somewhere below —10 deg F.) At a sufficiently high potential, in the work coil, the gas will ionize, become a good conductor, and cause arcing.

The bottles that will hold the "special" argon are heated before they are filled to give the gas a dew

more on page 90

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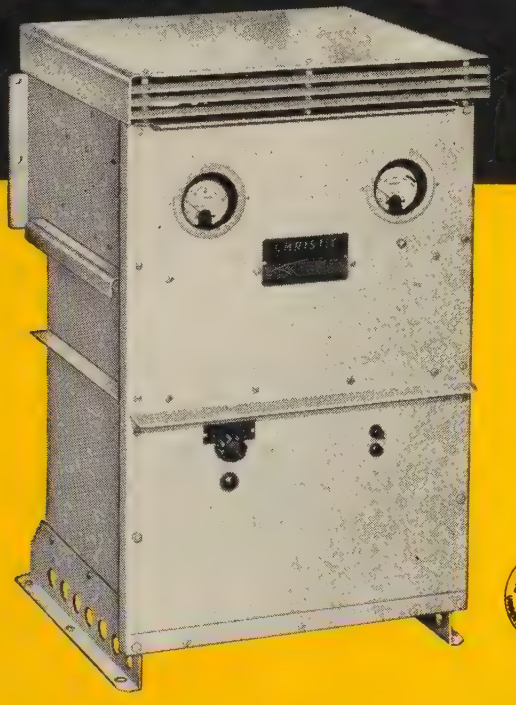
D-C POWER



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RELIABILITY

- Static-Tubeless
- All Silicon
- Built to MIL-E-4970
- Overload and Short Circuit Protection
- 500% Overload Capability

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CHRISTIE ELECTRIC CORP.

3402 W. 67th Street, Los Angeles 43, California

300 AMP. POWER SUPPLY

Model MH32-300KP4

Electrical Specifications:

NOMINAL D-C OUTPUT:
28 v. @ 300 amp. (continuous)

VOLTAGE ADJUSTMENT RANGE:
22 to 32 v. d-c

VOLTAGE REGULATION:
±0.5% — combination of rated load and a-c input variations (Sensing: local or remote)

VOLTAGE RIPPLE:
1% rms. (—20°C to +55°C)

VOLTAGE RECOVERY (63%):
0.1 sec.— full load application or removal

D-C CURRENT OVERLOAD CAPACITY:
125% for 5 min. every 20 min.
250% for 5 sec. every 20 sec.
350% for 1 sec., 500% peak

A-C INPUT:
400-490 v., 3-ph., 57-63 cps.
(other voltages available)

A-C CURRENT AT 440 V.:
25 amp.

AMBIENT TEMPERATURE RANGE:
Operating: —55°C to +55°C
Storage: —62°C to +70°C

ENVIRONMENT, SHOCK, VIBRATION:
Built to MIL-E-4970

RADIO INTERFERENCE:
Built to MIL-I-26600

Mechanical Specifications:

CABINET STYLE: STATIONARY
Also other styles below

SIZE & WEIGHT:
19" W x 19" D x 31" H.— 355 lbs.

Standard Features:

VOLTMETER & AMMETER:
3½" ruggedized (MIL-M-10304)
Recessed behind removable panel

OVERLOAD PROTECTION:
Magnetic & thermal

PARALLEL OPERATION:
Includes load sharing provision

OTHER FEATURES:
Input Contactor, Pilot Light, Fan, Fan Failure Protection.

Over 200 Models in 6 Cabinet Styles

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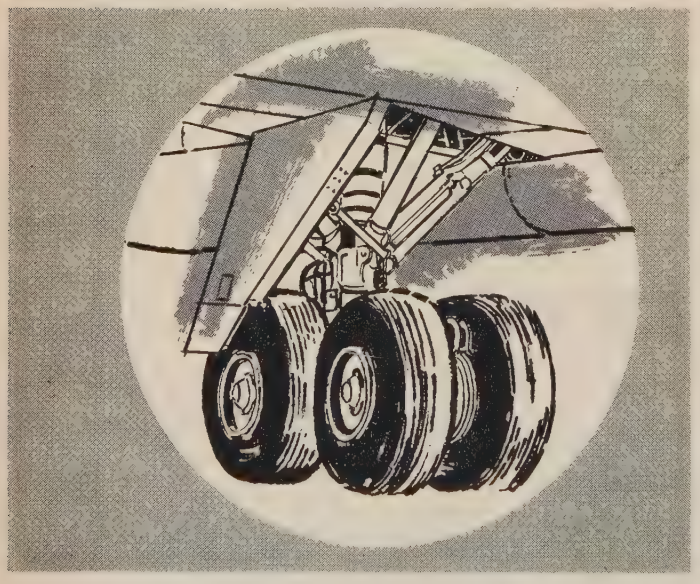
HERE'S WHERE ARMCO

17-4 PH
17-7 PH
PH 15-7 Mo

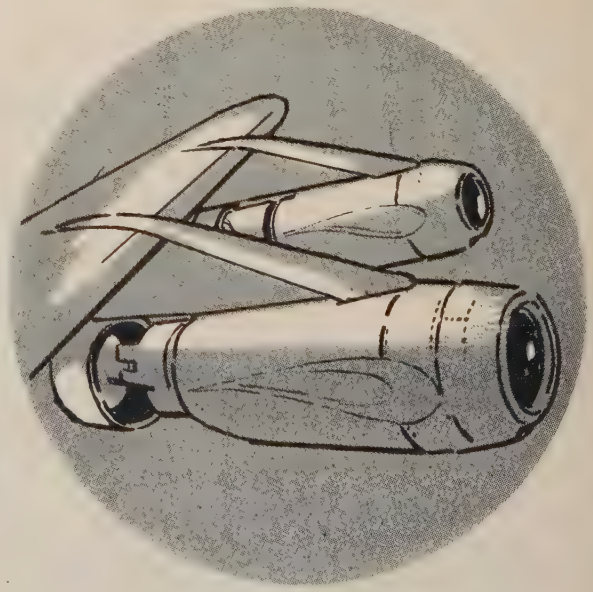
In both military and commercial jet aircraft, Armco's Precipitation-Hardening Stainless Steels are used to assure dependable performance in rugged service. All three grades of these aircraft stainless steels combine high strength-weight ratios with useful properties as high as 1000 F, good corrosion resistance, and producibility. Because of their unique advantages, engineers specify them for parts ranging from nose to empennage, from landing gear to flight control.

Stainless Steel



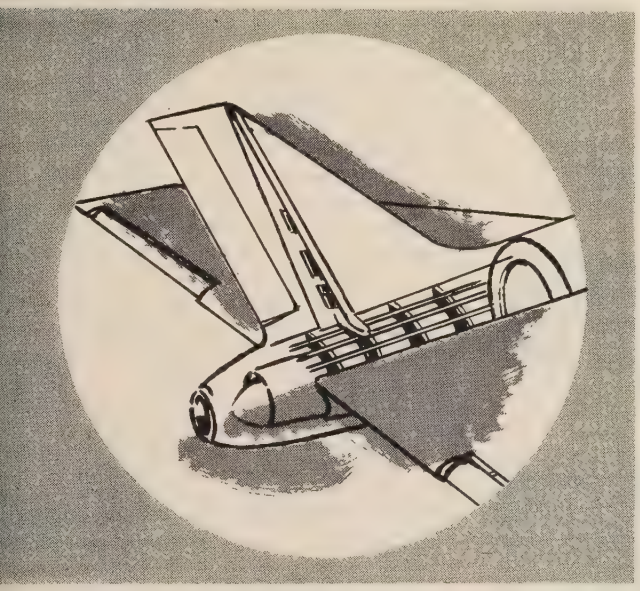
Reliable strength at elevated temperatures is assured by brake-system springs made of Armco 17-7 PH wire. Other vital parts of landing gear assemblies for both military and commercial jets are made of Armco 17-4 PH because it combines ultra-high strength and hardness with excellent corrosion resistance.

In pod and pylon structures as well as in jet engines, Armco's Precipitation-Hardening Stainless Steels resist the combination of high stresses and heat. Forged engine mounts, actuator shafts, fasteners, lever arms and engine parts are 17-4 PH; pod skins, engine vanes, pylon structural elements and thrust control devices are made of Armco 17-7 PH and PH 15-7 Mo.



STAINLESS STEELS

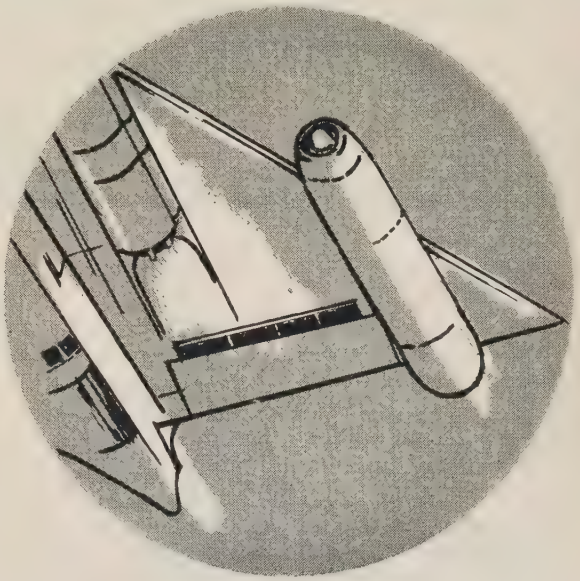
resist heat, stress and corrosion



Structural parts of fighter, bomber and airliner airframes are specified Armco 17-7 PH or PH 15-7 Mo because they provide the requisite combination of high strength-weight ratio, high temperature strength and good producibility. Ribs, stringers, longeron beams and frames, are typical elements made of 17-7 PH and PH 15-7 Mo. Armco 17-4 PH and PH 15-7 Mo are also used for many types of high strength fasteners.

Engine and aerodynamic heat have dictated the use of either Armco 17-7 PH or PH 15-7 Mo for control surfaces and skins of many supersonic airplanes. The unique combination of properties of Armco's special stainless steels not only meet severe performance requirements but make them especially suitable for honeycomb and other light-weight designs.

Use these special Armco Stainless Steels to help *you* overcome the design problems imposed by supersonic flight. Extensive data on properties pertinent to aircraft design and production are available. Write us for complete information on your specific requirements. Armco Steel Corporation, 1730 Curtis Street, Middletown, Ohio.



New steels are born at Armco

ARMCO STEEL

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation

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Portable Pyrometer Indicator Does Many Jobs

MINIMITE®

Null Balance, Potentiometer Type

The "MiniMite" Portable Potentiometer Indicator gives you laboratory accuracy in a rugged, versatile instrument. Use it conveniently for a wide range of temperature measurement, calibration and test purposes. Its dimensions are only 4" x 5" x 6"—weight is under 4 lbs. Accuracy is ¼ of 1% of scale range.

Temperature Measurement For direct temperature measurement, connect the "MiniMite" to a thermocouple. It's ideal for laboratory work, emergency operation or substitution for instruments under repair...also for many types of research and test work.

Calibration Use the "MiniMite" with equal facility for calibrating thermocouples, or both potentiometer and millivoltmeter-type instruments.

Scale Range Individual ranges on the "MiniMite's" double-range scale are almost 24" long. Choose from 49 different range combinations to cover temperatures from −300°F. to +3200°F. for all standard thermocouples, and millivolts from −6.2 to +62.

Write For Bulletin 64-2

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada:
THERMO ELECTRIC (Canada) LTD.,
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Please refer to page 282 for other Thermo-Electric ad.

Job-Designed Threaded Parts for Every Industry

Hassall

Here is a fast, dependable, low cost, quality minded source of supply for JOB-DESIGNED threaded parts and fasteners of all types, in any metal, to fit your own particular assembly problem. Recognize the fact that a fastener designed specifically to fill a seemingly complex assembly requirement can easily cost less than design modification to accommodate so-called standard rivets. Assembly costs are a very major part of manufacturing expense. Most of this is labor. The fastening medium itself is usually a minimum item. If a Job-Designed fastener makes assembly simpler and faster, permits the use of fewer fasteners, allows the designer functional freedom and improves product efficiency, yours is a specifying job well done. All these possibilities are available when you come to Hassall for design assistance and quotation on challenging, difficult or unusual rivets, threaded nails, drive screws and other cold headed parts. Short or long runs, pilot quantities, engineering counsel, over 100 years of intimate association with cold heading—and a deep appreciation and regard for the concept of value analysis—all are a part of the Hassall service to you.

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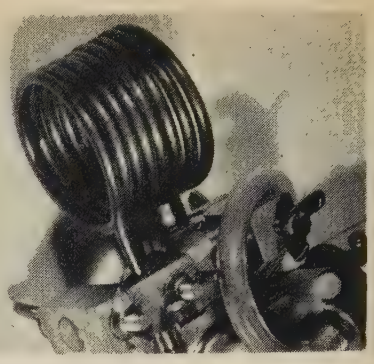


EXPENDABLE copper work coil is used to braze in "tight" areas.

point of about —60 deg F. Also under consideration is the use of vaporized liquid, which might make ionization still less of a problem.

At present, both the outside and inside of a union that is brazed must be purged. Studies are underway to see if it would be possible to develop a method for plating the interior tube ends to prevent oxidation. Another technique that is being looked into is the selective polishing of the tubing.

Brazing operators follow installation men

In operation, the split purge shield is held and centered over the joint to be brazed by two quick-acting clamps that also aid in sealing. The holding fixture aligns the tube ends so the union is free to rotate, insuring that the capillary gaps are within tolerance. The joints are purged for about two minutes before brazing.

The production concept, says NAA, is to have an installation crew apply union, holding fixture, and purge shield and start the purging cycle. The brazing operators then follow and braze the joint and submit it to inspection.—**IS**

Examples of Fluids Used in B-70 Systems

System	Fluid
Hydraulic.....	Oronite 8200
Engine Hydraulic	GE 81406 or 81644
Engine Lubrication.....	MIL-L-9236A or GE 81644
Fuel.....	JP-6

Write in No. 37 on Reader Service Card ➡

THESE NEW B-L-H GAGES

SIMPLIFY STRAIN MEASUREMENT

Since its initial development, some 20 years ago, the SR-4 Bonded Filament Strain Gage has simplified the approach to countless structural analysis and design problems, many of which would otherwise have been immensely difficult, if not impossible, to solve accurately.

Through the years literally hundreds of SR-4 gage types and configurations have been produced, each designed to solve a particular strain measurement problem as easily and precisely as possible.

Now, four new additions to the B-L-H strain gage family make possible still greater simplification of a variety of stress analysis jobs. One of them may be the answer to your problem.

STRAINLINE PHOTOELASTIC STRAIN GAGE

For the researcher or engineer who would like direct indication of strain, without resorting to electronic instrumentation, time-consuming connections, etc., the new Strainline photoelastic strain gage is an ideal solution.

Small, rugged, very simple to install and use, Strainline gages provide immediate, visual indication of strain magnitude. Each gage displays a series of visible transverse interference lines. When it is bonded to a surface undergoing strain, these lines are displaced along the length of the gage. The magnitude of displacement, with respect to a fixed scale on the gage mask, is directly proportional to the strain.

Unlike other photoelastic devices, the Strainline gage has negligible transverse sensitivity . . . no correction of readings is necessary. Its fringe lines are sharper and easier to read accurately (to better than 50 microinches per inch) in either natural or artificial light.

Strainline gages are available with gage lengths of ¾" and 2". For more information ask for Product Data 4325.

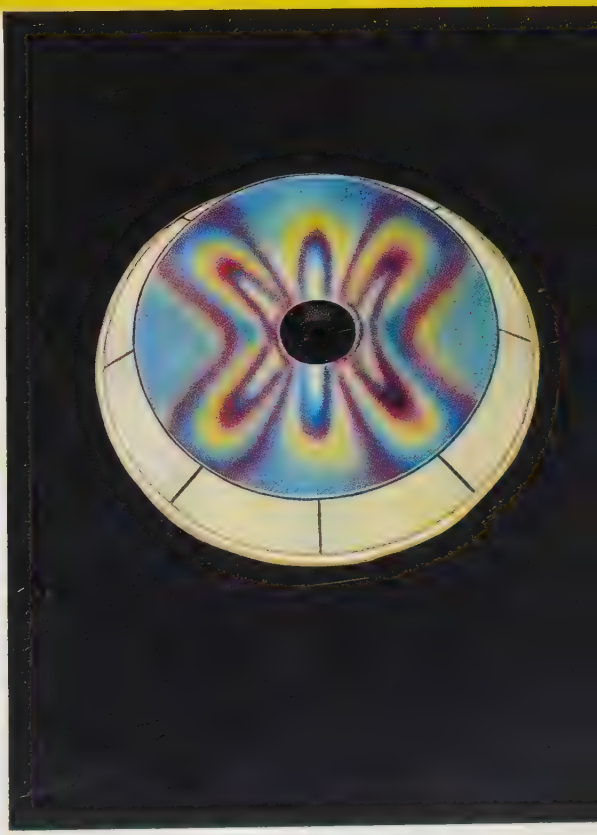
STRAINLINE PHOTOELASTIC STRAIN COMPASS

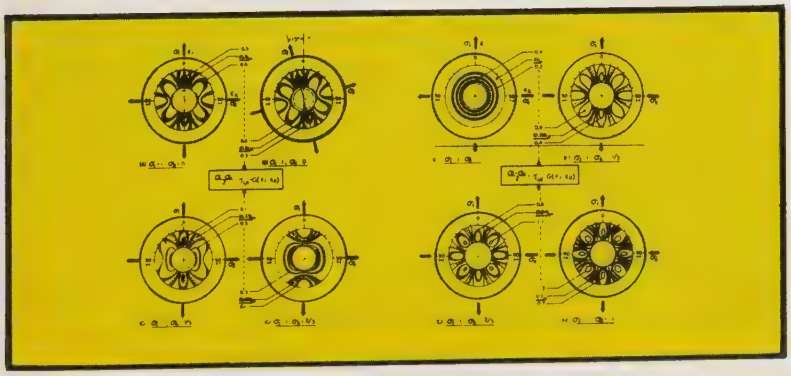
A natural companion to the Strainline gage is the Strainline compass. A truly unique photoelastic device, this small, circular gage provides quick visual indication of strain direction.

When a surface to which it is bonded undergoes strain, a symmetrical pattern of interference fringes appears on the face of the gage. The axes of symmetry of this pattern provide clear, immediate indication of the directions of principal strain.

A number of Strainline compasses, bonded to a test area may be photographed or observed simultaneously to determine localized strain direction over the entire area at any given instant.

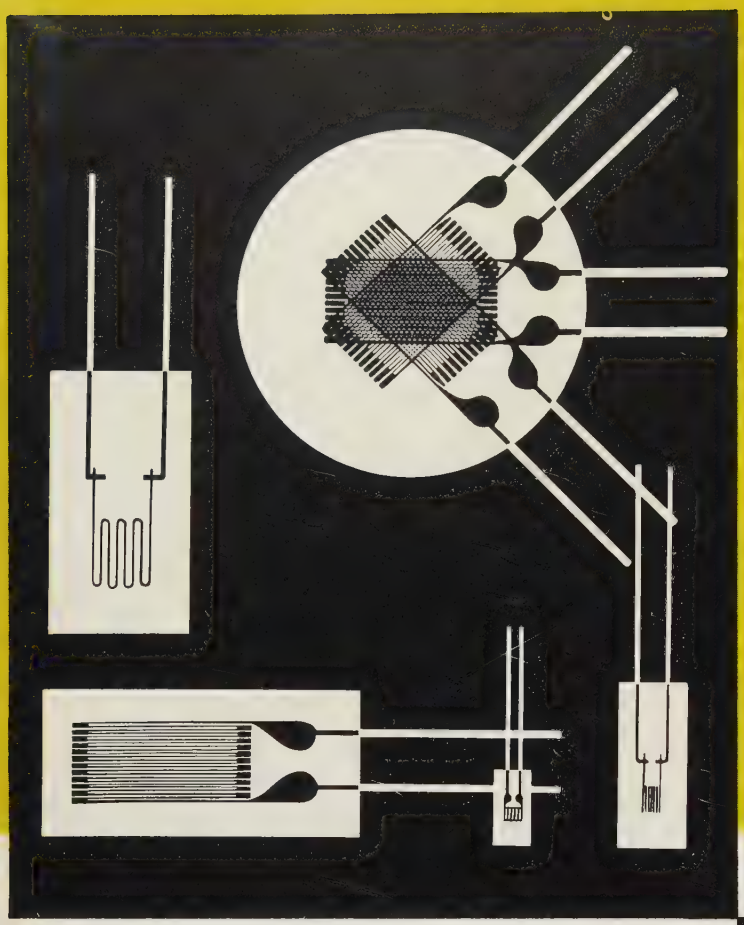
Strainline compasses are available with diameters of ⅜" and 1". For more information ask for Product Data 4326.





Theoretical shearing stress distribution for different stress ratios.

MORE INFO SR-4® STRAIN GAGES ON NEXT PAGE



SR-4® SELECTED MELT SELF-TEMPERATURE-COMPENSATED STRAIN GAGES

Probably the easiest way to compensate for temperat effects on strain gage readings is to use a gage which "matched" to the material of the surface under test

A new and complete line of these matched, or "Select Melt," gages of both wire and foil grid construction now available from B-L-H for use on a variety of m terials. Produced from alloy batches or "melts" wh have been carefully selected to exhibit certain pre termined thermal coefficient of resistance charact istics, these gages produce apparent strains of no m than $\pm 1\ \mu''/''/°F$ over the range of from 50 to 250

Most of the commonly-used SR-4® wire and foil str gage types are now available with Selected-Melt gr Three characteristic melts are offered for each g type, making Selected-Melt strain gages applicable materials having thermal expansion coefficients o (e. g., mild steel), 9 (stainless), and 13 (aluminu parts (± 1 part) per million per °F.

Melts are also available on special order for materi having other coefficients.

Ask your SR-4® Strain Gage representative how m "Selected-Melt" gages can fit into your testing proble

For more information ask for Product Data 4313.

SR-4® UNIVERSALLY-TEMPERATURE-COMPENSATED STRAIN GAGES

Although it serves a useful and important function, each self-temperature-compensated strain gage is necessarily restricted in use to the specific material for which it is intended and over a limited temperature range.

The new universally-temperature-compensated gage, however, may be used with a high degree of accuracy on almost any material. In addition, it will provide compensation over an extremely wide temperature range.

The temperature response characteristics of this remarkable new gage can be changed by varying the parameters of a simple external circuit. Two models are available, each with a gage length of ½". Type FNB-50-12E, on a phenolic base, is recommended for use from −320°F to +500°F.

Type FNH-50-12E, on a strippable vinyl base, may be used from −320°F to +850°F.

For more information ask for Product Data 4321.

AT YOUR DOORSTEP . . . The world's most complete strain gage line.

All Baldwin-Lima-Hamilton SR-4® Strain Gages, instruments and accessories are now carried in stock for immediate delivery at 15 strategic points throughout the country. Write for the address of the BLH Sales-Engineering Representative nearest you.

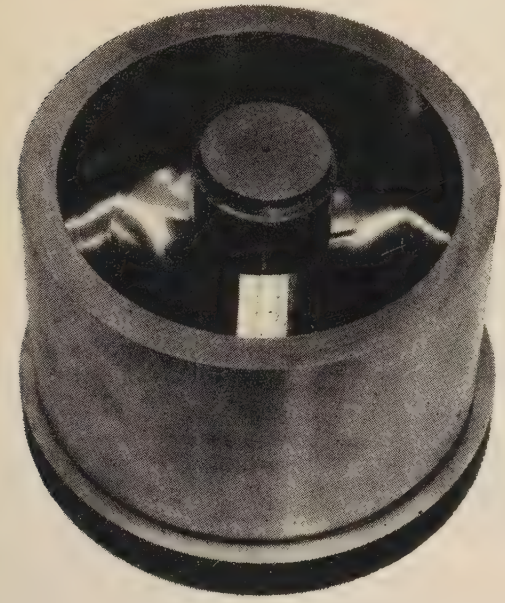
BALDWIN · LIMA · HAMILTON

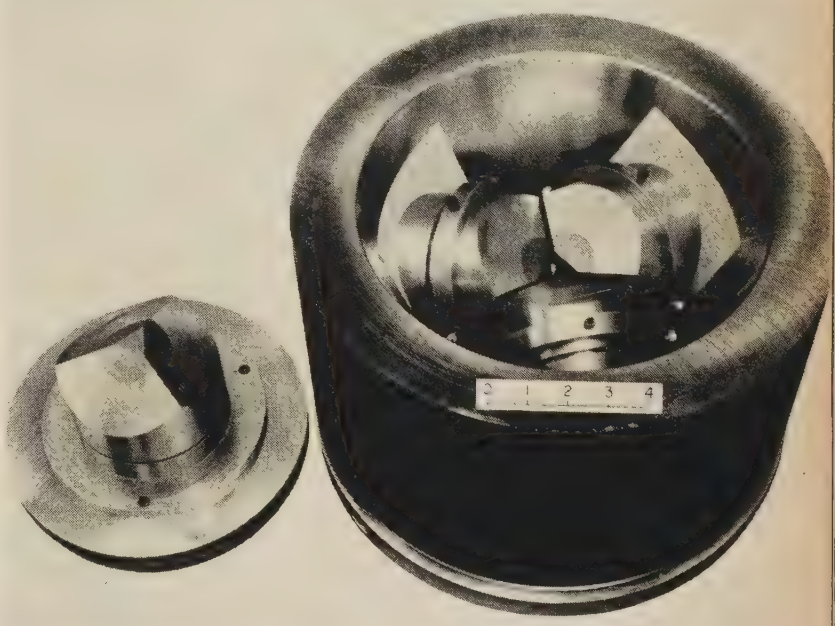
Electronics & Instrumentation Division

Waltham, Mass.

BALDWIN BLH LIMA-HAMILTON

COMPACT wedge-type high pressure apparatus designed and built by NBS (below). External force is applied only to the upper anvil. Right: Large multi-anvil high pressure device designed to produce pressures of up to 600 tons. Each triangular anvil face applies force to one side of a tetrahedron of pressure-transmitting pyrophyllite.





100,000-atm pressures

produced for materials studies

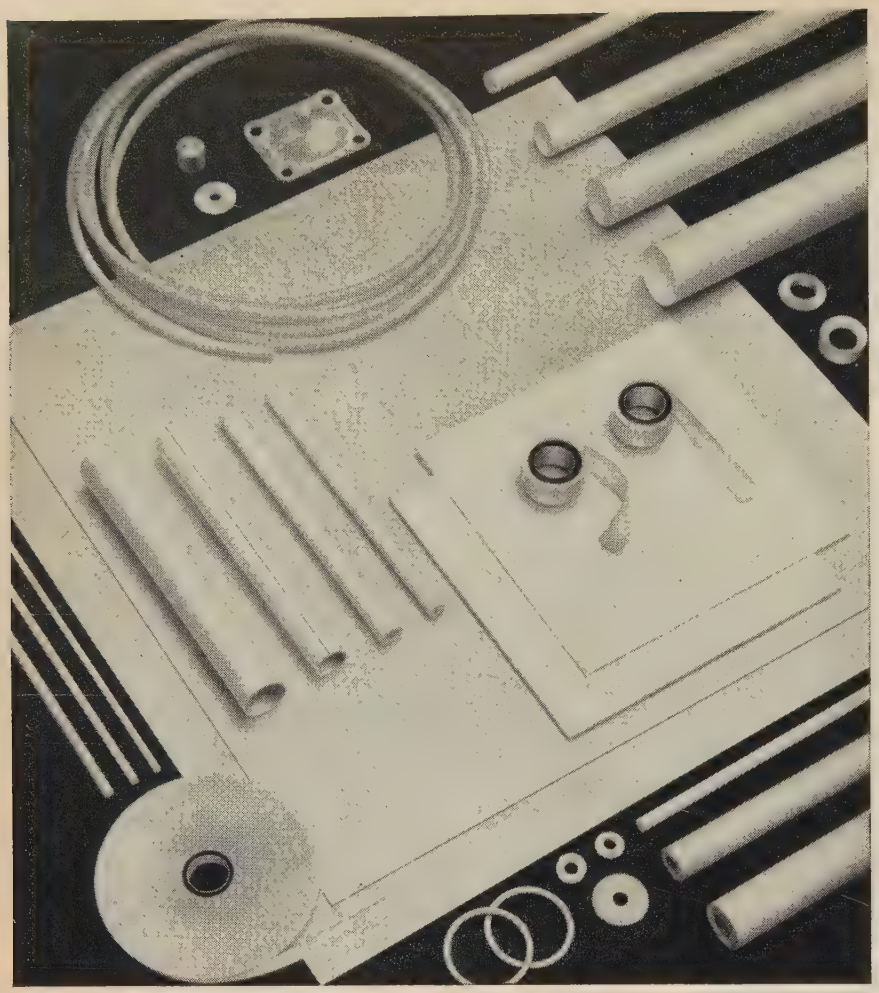
Pressures up to 100,000 atm can now be generated with a new apparatus used for the study of materials properties—yet the device is so compact and simple that it can be operated by a conventional hydraulic press.

A HIGHLY compact apparatus producing pressures of 100,000 atm and more has been designed by E. C. Lloyd, U. O. Hutton and D. P. Johnson at the National Bureau of Standards, Washington 25, D. C. The device was built for the study of material properties at high pressure, so that NBS scientists would be able to establish "fixed points" on the pressure scale and devise improved pressure measurement techniques. It produces pressure by applying force against each face of a regular half-inch tetrahedron of pyrophyllite (hydrous aluminum silicate).

Other devices for a like purpose have four independent hydraulic rams applying forces to the faces of the tetrahedron. In the NBS design, external force is applied to only one of the four anvils—wedge reaction forces act on the other three anvils. Because only one external force is needed, the apparatus can be used in a conventional hydraulic press. It has a diameter of eight inches at its lower bolster.

While a specimen is under high pressure, four electric connections through the anvils permit resistance-heating of the specimen and measurement of its temperature, electric resistance, or other quantities. Other advantages of the NBS apparatus are easy manipulation and alignment of the anvils and quick assembly and disassembly.

more on next page



Now you can do even more with TEFLON – made bondable by R/M

Time was, you'd often rule out "Teflon"* where it was sorely needed, simply because you couldn't make anything adhere to it.

But not now. R/M has perfected a process that makes "Teflon" easily bondable to other materials and to itself with commercial adhesives. Now you don't have to design intricate "Teflon" parts in a single piece or devise elaborate and costly fastening methods.

R/M can supply "Teflon" sheets and tape with bondable surfaces where you specify them. Thus you can use the remarkable electrical and chemical properties of "Teflon" without worrying about how to make it stay put. In fact, you can take advantage of bondability and non-bondability in the same R/M "Teflon" part.

A lot is happening in "Teflon" daily. To keep up with it, talk "Teflon" with the R/M man—learn of R/M's *complete "Teflon" service* that can help you improve design and increase reliability even while cutting costs. Call one of the offices listed below or write Plastic Products Division, Raybestos-Manhattan, Inc., Manheim, Pa.

*Du Pont trademark for its TFE-fluorocarbon resin

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SPECIALISTS IN ASBESTOS, RUBBER, SINTERED METAL, ENGINEERED PLASTICS

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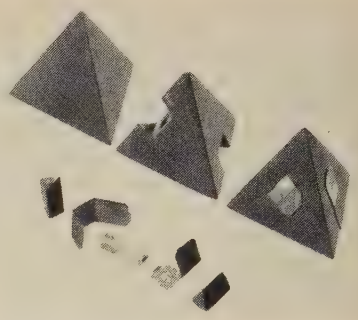


PYROPHYLLITE tetrahedrons and details of pressure cell assembly used in NBS' apparatus. The tetrahedron shows notches and a hole to receive the specimen. Silver foils and prisms to fill the notches and the specimen (in a sheath of silver chloride) are shown in the relative positions they occupy when assembled in the pressure cell.

The four anvils have tungsten carbide tips. These bear on the faces of the tetrahedron of pressure-transmitting pyrophyllite in which the specimen is embedded. The tip of each anvil is ground to a flat triangle and transmits pressure to one of the faces of the tetrahedron. The vertical anvil is forced down by the press; the other anvils transmit reaction forces from a conical retaining ring on which they are seated. Forces are thus applied to the tetrahedron from four directions. These forces are very nearly equal, and there is substantially equal motion of each anvil toward the tetrahedron's center.

The retaining ring and the anvils (except for the tips) are made of SAE 4340 steel heat-treated to R_C 40-41. Repeated applications of 100-ton loads have caused no permanent deformation of either the anvils or the retaining ring.

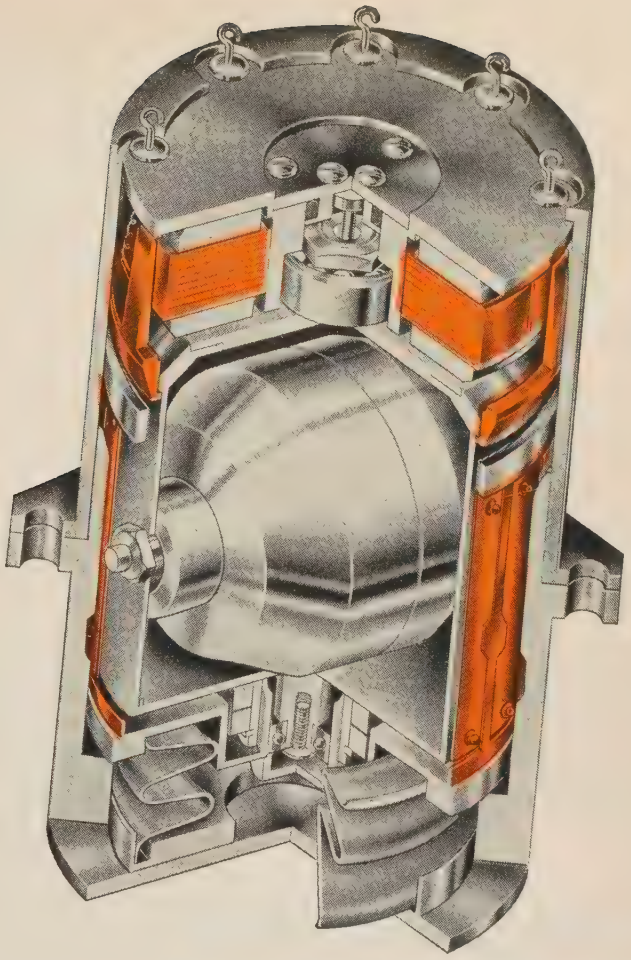
The inner surface of the retaining ring makes an angle with the horizontal that is nearly the same as the angle between the faces of the tetrahedron (70.528 deg). It is inclined about one degree more, however, to compensate for the friction between the butt ends of the anvils and the conical surface. The coefficient of friction is about 0.01 with Teflon lubricant. This friction is held to a minimum for satisfactory operation.

Several materials have a low coefficient of friction under heavy loading and appear suitable for use as lubricants in this case. Sheet

more on page 96

Ketay 2″ floated rate gyro controls damping from −54° to +74° C.

... saves space, weight, wattage and wear



Ketay has been successful in developing a floated rate gyroscope with a unique bellows and spring fingers system which compensates for temperature changes. Fluid viscosity is allowed to change freely, while the damping gap is controlled instead. This ingenious shear damping principle offers true "second order performance." No heating is required from −40° to + 74° C.

THIS UNIQUE KETAY FLOATED DESIGN FOR TELEMETERING AND INSTRUMENTATION OFFERS:

- increased shock (150G) and vibration (25G) resistance.
- gimbal support on precision ball bearings and support independent of torsion bars, permitting gimbal balance to exceptional accuracies.
- DC motor with direct battery operation, resulting in rapid run-up.
- AC motor without brushes, achieving longer life.
- AC or DC pick-offs. AC units give high output: 7½ volts per degree of gimbal deflection.
- 200 turn wire wound potentiometer

TYPICAL RG 20 SPECIFICATIONS

Rate (deg/sec)	±30
Natural Frequency	25 cps (min)
Size	Diameter 2″ Length 2⅞″
Damping (Ratio to Critical) over temperature	.07 ±0.2
Spin Motor	115V Line to Line 3φ 400 cps
Pickoff Type	Inductive
Excitation	26 VRMS 400 cps
Sensitivity (v/deg/sec)	0.2
Threshold (deg/sec)	0.06
Weight	1¼ lbs. (max)

For detailed specifications and drawings write to:

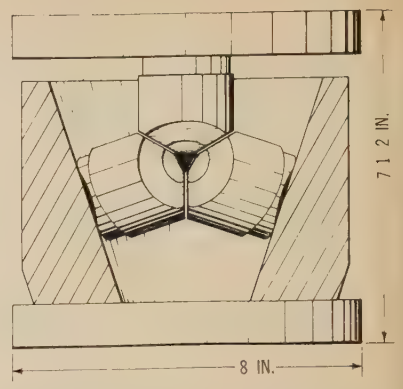
KETAY DEPARTMENT

NORDEN
DIVISION OF UNITED AIRCRAFT CORPORATION
Commack, Long Island, New York

Write in No. 39 on Reader Service Card at start of Product Preview Section

Teflon of 0.003 in. thickness was found to be good; it also provides the necessary electric insulation between anvils and ring when changes of electric resistance with pressure are studied.

When the apparatus is used for the study of such resistance changes, the specimen is inserted in a hole (of up to ⅛ in diameter) drilled from edge to edge of the tetrahedron. Pieces of silver foil are put in contact with each end of the specimen, and bent to present an exposed surface to each of the anvil faces. One end of each foil is in position to make electric contact with one anvil. The remaining notches in the edges of the tetrahedron then are filled with prisms of pyrophyllite. This arrangement provides an electric lead via each of the four anvils, and a four-lead circuit can be used for resistance measurements.



DOWNWARD ram force is exerted on the upper anvil of the NBS apparatus. This force is balanced by the vertical parts of the wedge reaction forces in the lower three anvils (one of which is not shown).

Measurements of resistance vs pressure have been made with specimens of antimony, barium, and bismuth. The results agree well with those reported by other investigators. The values of the ram forces required to reach the first resistance transitions of barium and bismuth show that about 10 per cent of the total applied force is lost to gasket forces and to the internal friction of the pyrophyllite.

NBS believes that other pressure-transmitting materials besides pyrophyllite should be studied for use in tetrahedral pressure cells. It also says that certain combinations of tetrahedron and specimen sheath materials may have better properties and may improve the uniformity of the pressure applied to the specimen.

If a larger tetrahedron were used for a given specimen size, pressure would be more and the proportion of force taken by the gasket should be reduced. NBS has built such a larger apparatus to study the advantages of size increases. The new device is designed to apply forces of up to 600 tons to tetrahedrons that are about one inch long. If it is successful, it will have proved the feasibility of a two-stage device in which a small tetrahedron is embedded in a tetrahedron of, say, three inches on one side. The forces for supporting the second-stage anvil would be supplied by the pressure in the large tetrahedron.—**RH**

STERILAB

CLEANED FOR "ON TARGET" RELIABILITY

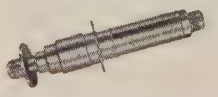
Roylyn's ultra-modern new ***STERILAB***, among the finest of "clean rooms" in the country, is now provided for assembly, testing and packaging of vital components used in the missile industry. An example is this new ultrasonically cleaned twin-mounted swivel connector which helps to keep SAC's Hound Dog flying. It is designed and qualified to MIL-J-5513A. Compact, of stainless steel, and weighing only 9 ounces, this startling new ball bearing connector operates in the engine oil system of one of America's finest missiles. Working under pressures of from 0 to 3000 psi, and at temperatures of from —65°F to 275°F, these advanced design connectors feature low rotating torque values under full operating pressures, in both pneumatic or fluid systems.

Airaterra engineering and design makes possible the adaptation of this and other swivel connectors to meet your specifications.

SOME OF THE OTHER POPULAR ROYLYN COMPONENTS

• Remote Disconnect Couplings

• Pneumatic Rise-Off Disconnect



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AIRATERRA • 620 PAULA AVENUE • GLENDALE 1, CALIFORNIA "THE BEST CONNECTIONS IN THE WORLD"

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RAPID READOUT

FOR CALIBRATION AND ADJUSTMENT
OF POTENTIOMETERS AND INSTRUMENTS
WITH POTENTIOMETER OUTPUTS

LEONARD SELF-BALANCING RATIOMETER

Please note these features of the Leonard Model 700320 Ratiometer:

***DIGITAL READOUT *DUAL CHANNEL *INTERNAL CALIBRATION *ACCURACY TO .0005VR**

Wallace O. Leonard, Inc. offers complete integrated facilities in engineering, production and testing, specializing in sophisticated systems and instruments for aircraft, missiles and ground support. Through pride in workmanship, Leonard craftsmen have established a high level of quality which has been recognized throughout the industry. More than 200 distinct and different products have been designed and manufactured, ranging from pressure switches to force-balance servo pressure computers used in missile guidance and control. Please discuss your requirements with our engineers.

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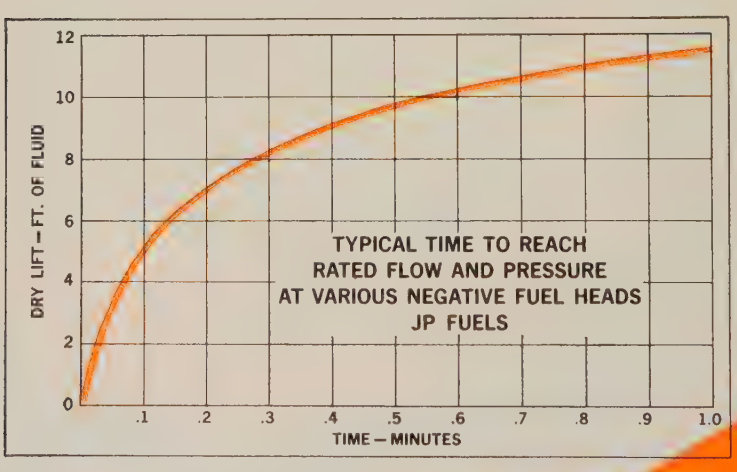
See the Ratiometer demonstrated at the **ISA FLIGHT TEST SYMPOSIUM,** suite 180-181, Hotel del Coronado, San Diego, Calif., May 2-5

Write in No. 41 on Reader Service Card at start of Product Preview Section

TAPCO FLUI

SELF-PRIMING PUMP FOR THE NORTH AMERICAN A3J FEATURES 2-SPEED MOTOR

This is the main fuel booster pump for the North American A3J Vigilante. It was designed by TAPCO on a unique "snorkel" principle to allow proper fuel flow under all conditions . . . normal-G, negative-G, and inverted flight. Fuel intake is switched to either end of the 4-foot inlet tube by a gravity selector valve to meet flight conditions, and the rating is maintained from 80 gpm at 7 psi to 130 gpm at 25 psi. For economical operation at cruise, the 200-volt ac motor has two selected speeds. Utilizing TAPCO's efficient method of vapor-separation, this snorkel pump helps make possible the high rate-of-climb and altitude performance of this Navy attack-reconnaissance aircraft.



Graph above shows dry lift capability of TAPCO *self-priming centrifugal pumps.*

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TAPCO GROUP

Thompson Ramo Wooldridge Inc.

DEPT. SA-560, CLEVELAND 17, OHIO

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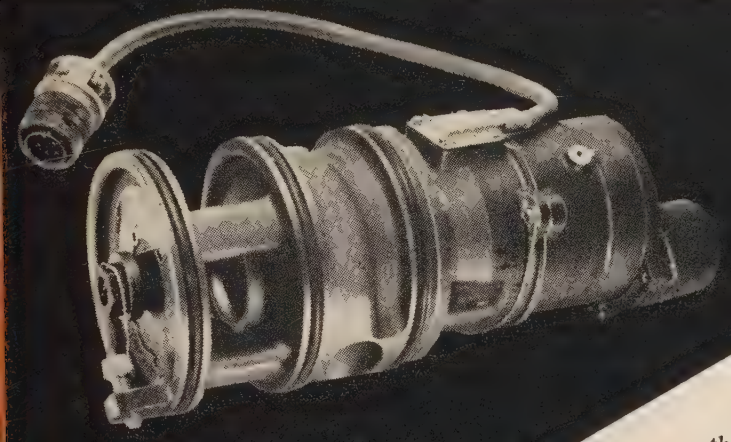
D SYSTEMS

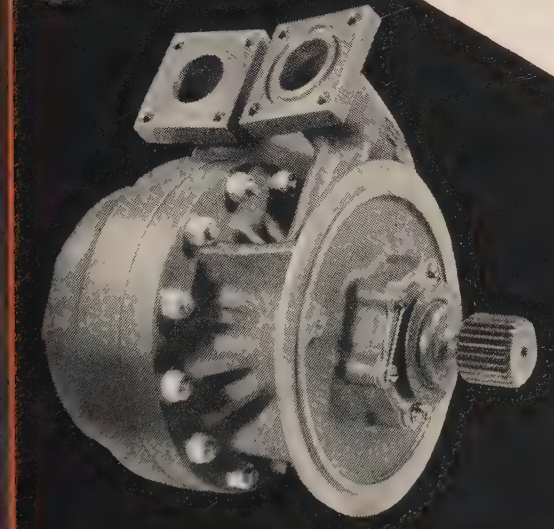


PLUG-IN PUMP FOR THE CONVAIR 880

This submerged booster pump can be removed for routine inspection without draining fuel tanks. The pump is self-priming and thermal-protected for aircraft safety. It handles 35 gpm at 13 psi, with power supplied by an integral 200-volt, four-cycle ac motor. This TAPCO pump is being installed on all production models of the Convair 880 and 600 jet airliners.

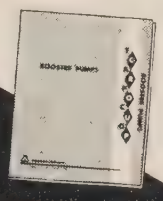
TAPCO'S 1-MILLIONTH CENTRIFUGAL BOOSTER PUMP

This 28-volt dc unit, with a rating of 22 gpm at 27 psi, is the *one-millionth* TAPCO centrifugal booster pump to come off our assembly lines. These pumps have piled up outstanding performance records with Boeing, North American, Lockheed, Republic, McDonnell, Northrop, Convair, Grumman, Chance Vought, and other aircraft companies. More than 20 years of experience have made TAPCO the leading designer and manufacturer of aircraft and missile pumps to meet increasingly severe conditions of altitude, rate of climb, pressure, gravity and fuel chemistry.



WATER-INJECTION PUMP FOR THE BOEING 707

This compact water-injection pump is used on each of the four engines on Boeing's 707-120 jet stratoliners. It develops 40-80 gpm with a maximum discharge pressure of 400 psi. The regenerative pumping principle permits high pressures and high flow at a relatively low engine-pad speed. Additional developments by TAPCO after qualification and acceptance has further increased the useful service life of this pump by 500%.



Write on your company letterhead
for our Pump Data Folder

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Weather-proof silicone rubber seals last longer than organic rubber...reduce costs

Organic rubber seals fail rapidly when exposed to the sun's ultraviolet rays, ozone, rain, sleet or snow. Plasticizers used in the rubber to give low temperature flexibility leach out, causing the seals to harden and crack and bond to mating surfaces. Frequent and costly changes are necessary to maintain an effective seal.

CHR silicone rubber seals on the other hand provide excellent resistance to the destructive attack of sunlight, time, weather and ozone. Though initially higher in cost, silicone rubber is actually more economical in the long run due to a superior combination of properties, which assure a more permanent, more dependable seal. Silicone rubber with high tear, flex and abrasion resistance, even after long weather exposure, is most economical for many ground support equipment applications.

The advantages of silicone rubber have long been recognized by aircraft manufacturers and it is used extensively on all commercial and military jet aircraft in the form of inflatable canopy seals, fabric-covered aerodynamic seals, airframe and engine seals, firewall seals, door and window seals, gasket and coated fabrics.

CHR specializes in the compounding, fabricating and development of silicone rubber seals for jet aircraft and missiles. As skilled fabricators of silicone rubber combined with fabrics, Teflon* or metals, we can help you solve your sealing problems. We invite your inquiry.

CHR

COHRlastic Aircraft Products: Airframe and engine seals, firewall seals and coated fabrics.

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*Reg. T. M. DuPont

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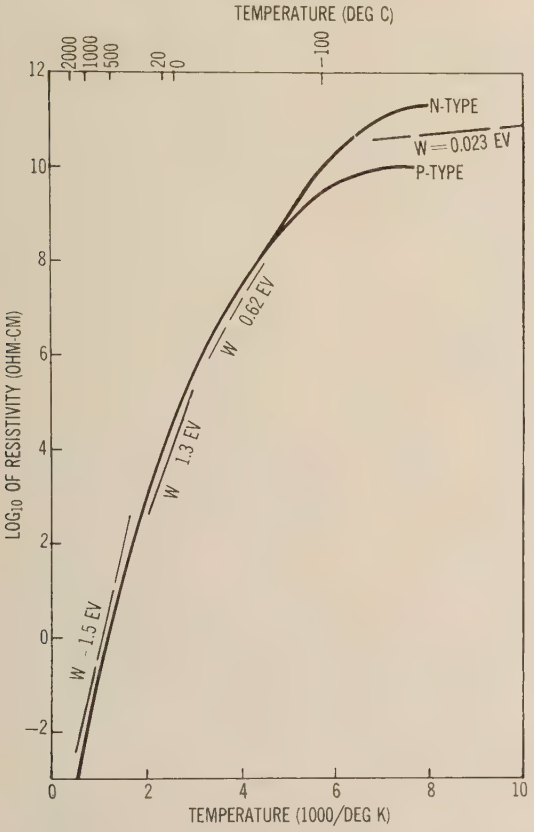
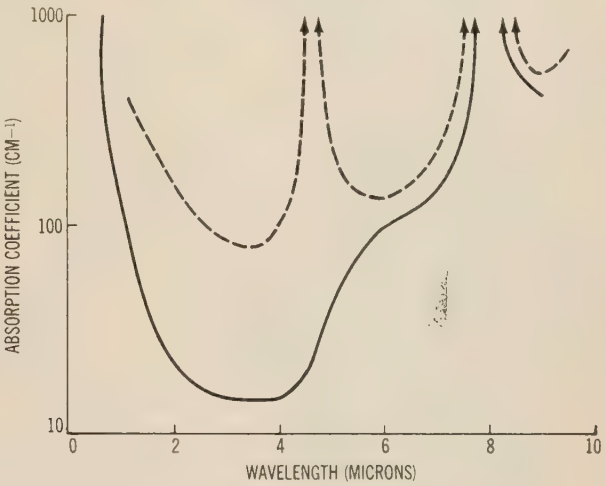




ELECTRIC RESISTIVITY of zone-refined, doped boron vs temperature as given by A. K. Hagenlocher (left). Boron's resistivity is affected to some extent by purity: at the lower temperatures, lower purity results in a decrease in resistivity. Above: Optical characteristics of boron as reported by Gaule, Breslin, Pastore, and Shuttleworth. Although opaque in the visible region, boron transmits considerable portions of the infrared spectrum and may be useful as a window for wavelengths from one to eight microns.

Boron:

impressive properties, impressive problems

Boron compounds have been developed for a number of aerospace applications, as in electronic equipment and reentry vehicles. Now boron itself is being eyed by researchers as a possible high temperature structural or electronic material. As this article notes, while many of its properties are impressive, so are its problems.

by D. N. Williams,
Assistant Chief, Nonferrous Physical Metallurgy Div., Battelle Memorial Institute*

BORON HAS many properties that make it look promising as a structural material: low density (2.3-2.5 gm/cc), high melting point (2000-2300 deg C), high room temperature hardness (2800 VHN), high elastic modulus (over 50×10^6), relatively high specific heat (0.263 cal/gm-C at 20 deg C and 0.31 at 900 deg C). Unfortunately, researchers so far have failed to find any cures for boron's drawbacks, which include a lack of ductility, a tendency to shatter at low impact, and extremely poor thermal-shock resistance (boron breaks up on cooling to room temperature from the temperature at which it was produced).

* Battelle Memorial Institute, Columbus 1, Ohio.

more on next page

BUILD ON . . .

Eastern

TEMPERATURE CONTROL EXPERIENCE

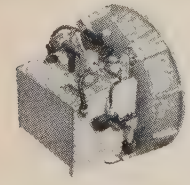
REFRIGERATION COOLING

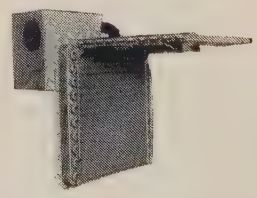
Sensitive aircraft and missile components and systems often require temperature control within close limits — while ambient temperatures fluctuate widely. Eastern refrigeration-type cooling systems are ideal for such conditions.

Designed for the strictest military requirements, these vapor-cycle closed-system packages are built around a highly efficient compressor powered by a special 400-cycle motor. Unique condensing and special cooling methods are called upon to meet the most unusual operating requirements, the most demanding specifications.

Capacities range from 100 to 6000 watts; operating altitudes extend to 100,000 feet. Some units, of the "boil-off" type, perform almost without regard for extremes in altitude and temperature.

Call on Eastern for imaginative solutions to *all* avionic cooling problems . . . and write for new Bulletin 360.





other refrigeration units for aircraft and missile electronics

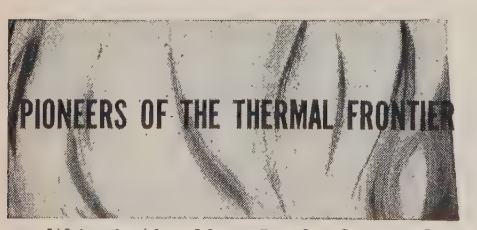


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Table I: Selected Physical Properties of Boron

Density near 20 deg C	2.3-2.5 gm/cc
Atomic weight	10.82
Valence	3
Melting Point	2000-2300 deg C
Boiling Point	2550 deg C
Specific heat near 20 deg C	0.263 cal/gm-deg C
Coefficient of linear thermal expansion near 20 deg C	8.3×10^{-6} per deg C
Thermal conductivity near 20 deg C	7.7×10^{-3} cal/cm-gm-deg C
Goldschmid atomic radius	0.97 angstroms
Natural isotopes	
Boron 10	18.83 per cent
Boron 11	81.17 per cent
Thermal-neutron absorption	
Boron	750 barns per atom
Boron 10	3990 barns per atom

Because of the structural needs of high performance vehicles, boron research is continuing. Last September, for instance, a conference on boron was sponsored by the Army's R&D Lab. The Defense Metals Information Center has collected as much information as is available on boron and summarized it in DMIC Memorandum 41.

Because of purity problems, the properties of boron as found by different investigators can be expected to vary. "Pure" boron may range from about 90 per cent boron (with the balance mostly magnesium and oxygen) to 99.9+ per cent boron. Impure boron is prepared by magnesium reduction of B_2O_3 (Moissan boron). Various steps may be taken to upgrade this material to relatively high purity. Much purer (99.9+ per cent) boron may be prepared by hydrogen reduction of boron tribromide on heated filaments. The principal impurities in 99.9+ per cent boron are silicon, carbon, and metal from the filament (most commonly tantalum or tungsten, though rhenium, quartz, and graphite filaments have also been reported).

Commercial production of boron by reduction of BCl_3 by hydrogen

more on page 106

Ultra high strength wire ribbon being formed into a rocket case on specially designed wrapping machine.

UNIQUE BENDIX WIRE *RibbonWrap* REDUCES WEIGHT, INCREASES RELIABILITY OF ROCKET CASES

lix has licked the problems of weight reliability in flight weight pressure ves- Secret of the Bendix-developed rocket : many tiny ultra high strength steel s formed by adhesive bonding into a y efficient ribbon. Weight and distribu- of the binding adhesive is precisely con- ed. Result—rocket cases with test gth as high as 531,000 psi, *equivalent hoop stress of 350,000 psi UTS in a homogenous case.* A specially designed Bendix machine generates the rocket case. The best wrap pattern for each case is mathematically determined and precisely controlled. Finished product is a rocket case tailor-made for configuration, strength and reliability.

For more complete information, write Rocket Equipment, Bendix Products Division, South Bend, Indiana.

The Bendix wire RibbonWrap gives you these important advantages:

Design Flexibility
Controlled Minimum Weight
Close Tolerances
High Temperature Strength
Shortest Prototype or Production Lead Time
Automated for Low Cost
Inherent Reliability

Bendix PRODUCTS DIVISION South Bend, IND.

Bendix AVIATION CORPORATION

Write in No. 45 on Reader Service Card at start of Product Preview Section

Titanium trims DC-8 airframe

(equals 5 passengers, or 1/2-ton of freight...*for life*

DOUGLAS AIRCRAFT COMPANY, INC., *has never built an airplane that failed to show a profit for its operators. Based on the experience of United Air Lines, the first carrier to fly the airplane, the latest Douglas ship, the DC-8 jetliner, indicates it will push this record forward. Here's how use of titanium contributes to the total efficiency of the airplane and what that efficiency means in dollars and cents.*

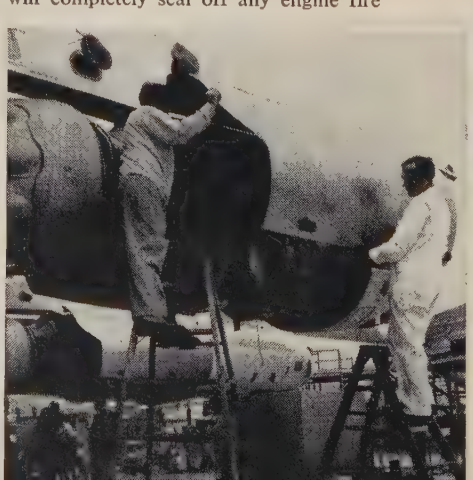
The flyaway airframe of the DC-8 jetliner provides its operators a basic economy almost anomalous in current design: payback on every flight without research or development costs to be amortized. That's how Douglas engineers state the value of titanium in achieving a minimum weight airframe structure.

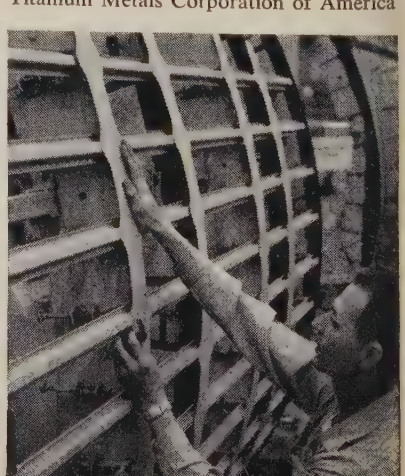
Primarily an aluminum ship, the DC-8 offered few possibilities for weight savings during design. But where weight could be reduced – in pods and pylons, rip stoppers and door doublers—titanium was selected: –600 pounds of commercially-pure grade Ti-75A for pods and pylons; 330 pounds of Ti-6Al-4V titanium alloy grade for rip stoppers and door doublers; 15 pounds of miscellaneous titanium forgings. Metal is supplied by Titanium Metals Corporation of America.

The net result is elimination of a half-ton of needless airframe weight for the 5,000 flights each DC-8 is expected to make during its seven-year write-off.

TITANIUM ACCESS DOOR, through which DC-8 engine will be serviced, is installed on the aircraft by two Douglas Aircraft Company, Inc. employees. Pods of the DC-8 have been so designed that titanium will completely seal off any engine fire

TITANIUM RIP-STOPPERS play essential role in Douglas fail-safe approach to airplane construction. DC-8 uses 330 pounds of Ti-6Al-4V alloy titanium produced by Titanium Metals Corporation of America





y 945 pounds

TITANIUM ACCESS PANEL which covers engine in DC-8, complete with titanium details, measures 102" by 76" and weighs 80 pounds. Cumulative tolerances are controlled so closely at Ryan that each door is interchangeable with any pod built for a specific airline. 600 pounds of titanium (TMCA grade Ti-75A) are used in DC-8's pods and pylons

erpretations of the value of weight savings include:

- DOUGLAS AIRCRAFT: "The 1,000 pounds (of weight saved) are equivalent to five passengers and their luggage for the entire life of the airplane."
- UNITED AIR LINES: "At the very least, the weight saved by titanium is equivalent to a half-ton of cargo. At mail rates, this would amount to a potential of $525 for each coast-to-coast flight."

ıy titanium?

anium, with a density of 0.163 lb/cu. in. is produced in engths equal to or surpassing steel on a strength-weight basis. resistance to atmospheric corrosion is permanent.

The reliability of titanium has been established with demonated clarity. Examples:

- DOUGLAS has employed titanium in every commercial transport since its first DC-7, where titanium in firewalls, nacelles and landing gear doors yielded 200 pounds of weight savings.
- PRATT AND WHITNEY AIRCRAFT reports that more than one million flight hours have been accumulated by more than 5,800 P & WA JT-3 and JT-4 engines using titanium components without a single failure of any titanium part, either through corrosion or mechanical damage. Both engines have been specified for the DC-8.
- Alluding to titanium's reliability as its "sleeper property," W. Stuart Lyman, Principal Metallurgist, BATTELLE MEMORIAL INSTITUTE, made this comment in a lecture in Los Angeles March 19:

"We have talked with metallurgists from three large users of titanium recently. To a man, they reported that once titanium passes receiving inspection, gets fabricated, passes final inspection, and gets assembled into the airplane, it is usually never heard from again."

titanium competitive in price?

AN AERONAUTICAL COMPANY, which fabricates the bulk of the nium assemblies employed in the DC-8, commands industry-le respect for its skill of craftsmanship and the attention to ail it brings to every job. Example: To guarantee maximum inliness, Ryan's DC-8 final assembly building in San Diego been so constructed that no doors or windows open in the ection of prevailing winds.

While overlooking no opportunity to impress upon emyees' minds that titanium metal costs more than steel, Ryan developed manufacturing techniques to fabricate titanium prices roughly equivalent to steel's. The spread between "input al" and completed assemblies is thus drastically narrowed e fabrication costs are, of necessity, far greater than raw terial costs.

Highlighting titanium's fabricability is Ryan's production he access panels which cover the DC-8 engines. These panels erally the doors through which engines will be serviced for – are made from three sections of 0.016" Ti-75A, 36" x 72", stretch-formed and welded together to form the skin of the hpleted door. Details, such as stringers, channels, ribs and mes, are then welded or riveted to the skin. The completed duct weighs 80 pounds and measures 102" long by 76" in the vature. Control of tolerance (cumulative tolerances are .005") is so highly developed at Ryan that these massive-earing access panels are interchangeable with any pod built a specific airline.

Where does titanium belong?

Titanium metal, built into the DC-8 as a basic design material, has been used in a variety of civilian and military applications in a direct volume-for-volume substitution for heavier materials to capture weight savings sufficient to permit improvements in systems or payload capacity.

Although such weight reduction programs and the attendant dollar value must be viewed in relation to the specific application, titanium's permanent resistance to atmospheric corrosion yields dividends immediately apparent to operators of commercial carriers. It means 8 to 10 trouble-free hours operation each day when maintenance means not only repair costs, but also downtime of expensive equipment.

In pods, pylons, landing gear doors, bulkheads, stringers, and a host of similar parts, titanium's weight savings are measured in *payback*. In projects such as solid and liquid propelled missiles, titanium's weight savings are measured in *payload*.

Why Titanium Metals Corporation of America?

Titanium Metals Corporation of America, the nation's only organization devoted exclusively to development, production and sale of titanium metal, has wide interest in establishing titanium metal only in those areas where it is of value to you.

The interest arises from the basic belief that a satisfied customer is a steady customer.

This interest is manifested in TMCA's genuine efforts to meet your delivery schedules; to provide you with whatever information you need concerning properties of titanium and manufacture of finished assemblies; and to pass on to you the price advantages gained through TMCA's technological progress.

Whether building new aircraft, or retrofitting operational ships, designing advanced missiles or modifying existing units, you can lick your weight bogey with titanium.

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Write in No. 46 on Reader Service Card at start of Product Preview Section

DISCERNING DRAFTSMEN THE WORLD OVER DEMAND IMPERIAL THE WORLD'S FINEST TRACING CLOTH

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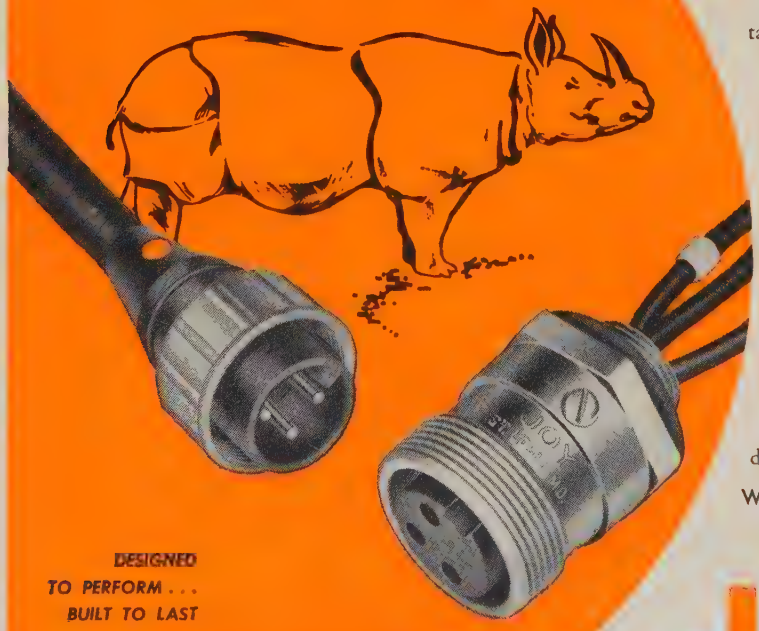
or graphite has generally resulted in purities of 96-98 per cent, with the principal impurity being carbon. Other production methods include the growing of primary boron crystal from a boron-platinum melt and anode transfer electrodeposition of boron carbide in a fused-salt bath. In the latter process, the purity of the material may reach 99.8 per cent. Zone refining has also been used; there is some evidence—particularly on the basis of optical properties—that it leads to significant improvements in purity.

The crystal structure of boron is incompletely understood so far. One form, reported by most investigators, is called beta-rhombohedral. It contains 108 atoms per unit rhombohedral cell, with an a_o of 10.14 angstroms and an α of 65.3 deg. This form occurs whenever boron is prepared at 1500 deg C or above or any other form of boron is heated above 1500 deg C and is believed to be structurally stable.

Two other well-documented forms of boron exist—alpha-rhombohedral and amorphous. The former may be indexed in the rhombo-

more on page 108

JOY. America's Only Electrical Connectors Fully Rugged-neered for the Really Tough Jobs!



DESIGNED TO PERFORM . . . BUILT TO LAST

If you're looking for electrical connectors durable enough to take the roughest, toughest demands of today's ground support equipment — you won't find more dependable units than JOY "Space Age" Electrical Connectors.

Proof? Joy Connectors have proved themselves on tough assignments before: into the hot depths of oil wells while carrying delicate recording instruments and holding against pressures to 20,000 p. s. i. . . . inside the hulls of submarines and withstanding deep sea pressures even during depth charges . . . carrying 7500 volts of power to giant strip mine shovels . . . feeding full power to nuclear subs with idle reactors while in port.

NO ONE MAKES 'EM LIKE JOY

JOY molded-to-cable connectors are completely watertight and moisture resistant . . . with full durability against distortion, impact, shock, and vibration . . . corrosion-proof . . . in many sizes and styles (with free technical service to discuss your *exact* needs).

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CD1159.1

JOY ELECTRICAL PRODUCTS DIVISION
1237 Macklind, St. Louis 10, Mo.
Exec. Offices: Henry W. Oliver Bldg., Pittsburgh 22, Pa.

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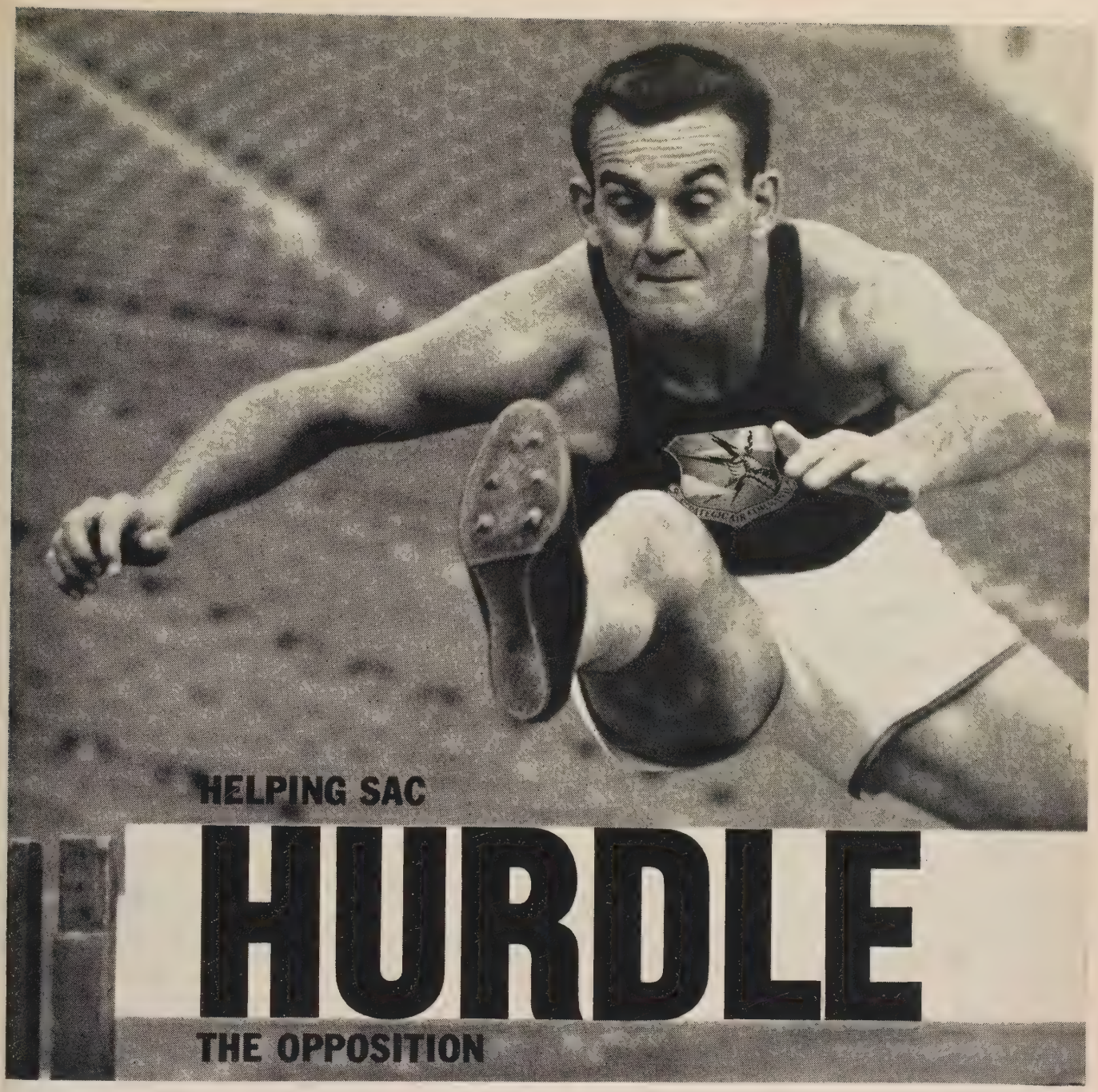


SAC is now off and running with its new Hound Dog missile. With the supersonic GAM-77 missile, the B-52 bomber can more easily hurdle ground defenses on the way to a target. In the short span of just 30 months, the Hound Dog air-to-surface missile grew from the drawing board to a powerful member of SAC's deterrent team.

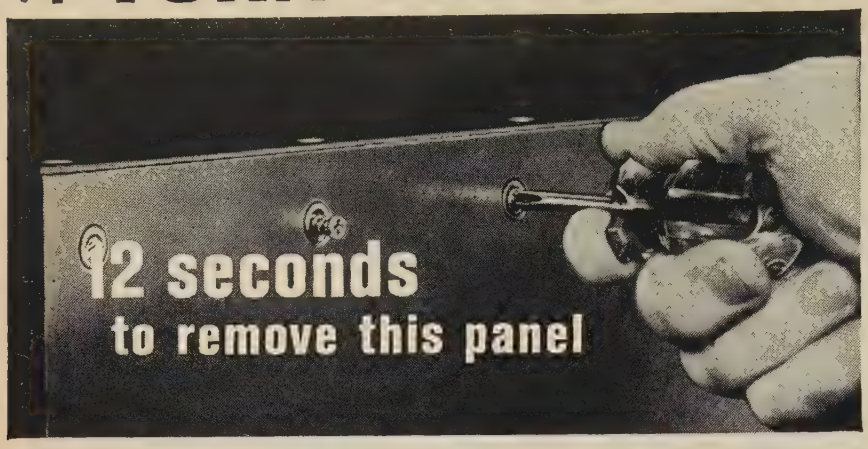
Silencing enemy ground defense centers while the mother ship speeds on toward the main target is just one of the jobs of the versatile GAM-77 missile. Slung beneath the swept-back wings of a B-52, a pair of GAM-77's can either clear a path for the bomber, or be sent right in on the main target itself. This triple-threat capability lets a single B-52 command a target approach corridor over a thousand miles wide.

To further confuse the enemy, these inertially-guided missiles can feint at pseudo-targets before turning toward their real objectives. Speed and altitude variations can also be programmed into the GAM-77's target approach.

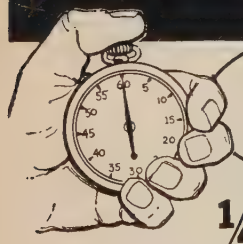
The Hound Dog missile greatly extends the useful life and striking power of SAC's B-52 bombers—the backbone of America's strategic power. The GAM-77 is being produced by the Missile Division of North American Aviation.

MISSILE DIVISION
NORTH AMERICAN AVIATION, INC.
Downey, California

¼-TURN FASTENERS



VERSUS SCREWS



Designed To SAVE YOU Time

CAMLOC ¼-TURN FASTENERS

The odds are in your favor by 5½-to-1 when you design-in Camloc ¼-turn fasteners. By actual test, you save that much time—compared to screws—in removal and replacement of these panels. What's more, there are no loose parts – Camloc fasteners are "captive" in the mating panels. By all odds, Camloc ¼-turn fasteners cost you less to use, save you time, save you effort in fabrication and service. Millions of fasteners in use today are proof of their outstanding, money-saving qualities. Write today for Catalog.

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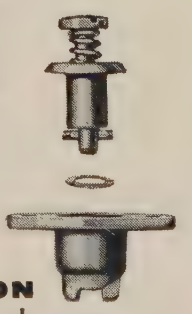

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Table II: Hardness of Boron as a Function of Temperature*

Temperature (deg C)	Vickers Hardness (100-g load)
20	2800
400	2000
790	1000
900	450

*Data from A. U. Seybolt.

hedral lattice with an a_0 of 5.07 angstroms and an α of 58.1 deg. It generally is observed in crystals grown from boron vapor between 800 and 1200 deg C and is also produced when primary boron is precipitated from a boron-platinum melt at 1200 deg C.

Under certain conditions of temperature and pressure, amorphous boron may form during vapor-phase decomposition below 1500 deg C. Examined by X-ray, it shows only two diffuse rings, which suggests a glass-like structure.

Tetragonal forms of boron have often been reported. However, it's probable that these represent a metal-boron compound of the type MB_{25} rather than pure boron. The metal atoms may be supplied by the filament on which the crystals are grown.

It is likely that all of the reported crystal modifications of boron—except for the beta-rhombohedral form—represent incomplete approaches to equilibrium, since all transform irreversibly to beta-rhombohedral when heated. If this is true, the large variety of forms that have been observed may be explained on the basis of growth kinetics resulting from differences in the method of preparation.

As *Table I* shows, boron has a number of attractive physical properties, which make it useful in special environments. The *Graphs* include plots of the electric resistivity of boron as a function of temperature. The material has a high negative coefficient of electric resistance. Resistivity is affected somewhat by purity; lower purity results in a decrease in resistivity at lower temperatures.

Crystal structure and methods of growth may also affect the resistivity — some crystals grown from a boron-platinum melt reach a resistivity plateau of only about 50

more on page 112

Bell-powered Agena satellites in orbit — symbolized.

THE ENGINE WITH THE FUTURE

Reliability . . . Efficiency . . . Flexibility.
In space, these words have a million-dollar meaning.

Vast sums of money and vital scientific data ride on these built-in attributes of Bell Aircraft's rocket engine for Lockheed's Agena satellite, second stage of the Air Force Discoverer series.

The Agena engine, designed with space in mind long before space became a household word, has fulfilled its every mission and has placed more tons of useful payload into orbit than any other power plant. Its operational reliability is backed by six years of development and 5,000 test firings.

This Bell engine now has re-start capability — the first in the nation. This means that its satellite can change orbit **in space** without the penalty of extra engines. Presently in production, this engine also is adaptable to new fuels and new assignments and, consequently, is programmed for important military and peaceful space ventures of the future.

Agena's engine is typical of the exciting projects in Bell's rocket propulsion center. It is part of the dynamic new approach of a company that's forging ahead in rocketry, avionics and space techniques. These skills serve all government agencies. Engineers and scientists anxious for a new kind of personal challenge can find it at Bell.

Niagara Frontier Division

BELL AIRCRAFT CORPORATION

BUFFALO 5, NEW YORK

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Marquardt Advanced Nuclear Systems for Air and Space

MARQUARDT EXPANDS WORK ON "PLUTO"

Broadened team effort with University of California's Lawrence Radiation Laboratory aims toward early feasibility demonstration of a nuclear ramjet reactor (Project PLUTO).

A supersonic, low-altitude missile capable of weaving, feinting and dodging unobserved by conventional radar while seeking out selected targets — this is to be the mission of the Air Force's proposed nuclear ramjet-powered vehicle of virtually infinite range.

As an integral part of the team which is contributing to this country's all-out race for supremacy in weapons, Marquardt is working with the University of California's Lawrence Radiation Laboratory on the nuclear ramjet program, known as Project PLUTO.

Marquardt's basic PLUTO effort concerns preliminary design of the nuclear ramjet and development of airborne reactor controls and other components for severe temperature and radiation environments. The multi-million dollar program supports a multi-phase corporate effort headed by the Nuclear Systems Division.

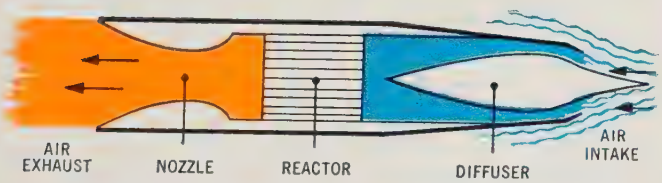
Other aspects of Marquardt's PLUTO effort include: support of LRL's feasibility tests on the non-flyable Tory IIA reactor; design and fabrication of significant portions of the reactor's control system, air ducts, flow instrumentation and remotely operated disconnects; fabrication and test of reactor core structural components; architect-engineering on the test air supply system; participation in a supporting program of environmental tests; and preliminary design of test facilities for full-scale power-plant development.

Highlights of the Corporation's other current nuclear programs include: exploration of both military and non-military applications for transportable reactors of advanced design, including their use for space power; development of the engine control system for the G-E nuclear turbojet; research studies of advanced space propulsion devices utilizing nuclear concepts; materials and processes work with molybdenum, other refractory metals and ceramics; and development of original nuclear instrumentation.

For a copy of Marquardt's new "Nuclear Systems" brochure, write to Mr. Aikman Armstrong, Chief Applications Engineer-Nuclear Systems, The Marquardt Corporation, Van Nuys, California.

Write in No. 80 on Reader Service Card at start of Product Preview Section

THE NUCLEAR RAMJET



Nuclear Systems Division of The Marquardt Corporation is engaged in a continuing search for engineers and scientists capable of contributing advances in nucleonics state-of-the-art. Current expansion within this division creates challenging opportunities for: REACTOR PHYSICISTS • CERAMICISTS • NUCLEAR ENGINEERS • METALLURGISTS.

Qualified men are invited to contact: Mr. Floyd Hargiss, Manager, Professional Personnel, The Marquardt Corporation, 16555 Saticoy St., Van Nuys, Calif.

NUCLEAR SYSTEMS DIVISION

THE Marquardt CORPORATION

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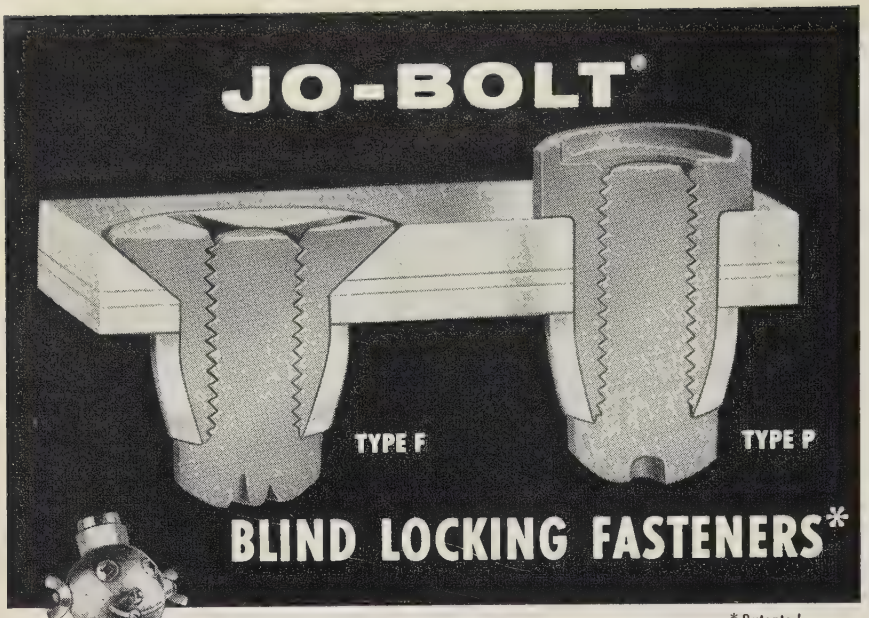
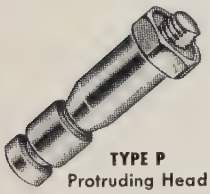


* Patented

DO IT BETTER · DO IT FASTER in missile/aircraft frame assembly

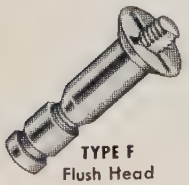
What happens in JO-BOLT Fastener installations can be seen at a glance, in the cross section above. The resulting clamp-up of sheets and structural members is tight and positive, 100% effective.

That's highly important . . . but not even the half of it. First, consider this . . . JO-BOLTS® are high-strength structural fasteners, typically providing: shear strength of 95,000 psi min. in steel types; 85% AN Bolt tensile strength in #10 and ¼" diameters; vibration resistance superior to bolts with lock nuts.



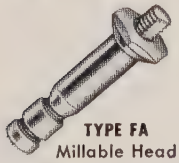
TYPE P
Protruding Head
Steel

Second, JO-BOLT Fasteners are lightweight and compact, allow savings in fastener weights averaging 50% or higher, often permit use of narrower and lighter substructures.



TYPE F
Flush Head

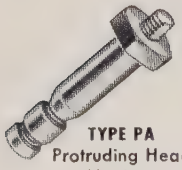
Third, JO-BOLT Fasteners can always be installed by one man from one side of the work . . . eliminating most common access and clearance problems.



TYPE FA
Millable Head

Finally, JO-BOLT Fasteners are foolproof and fast, can be popped into holes prepared and aligned for them, and driven to grip inside of seconds, always resulting in high-quality work, uniform and unmarred, regardless of worker skill.

They are so good, in fact, at fastening better and faster that they've been preferred and specified in practically all high-performance aircraft ever since introduction.



TYPE PA
Protruding Head
Aluminum

Write for illustrated booklet J 59. It lists specifications for all types, tells about A 286 Hi-Temp and other special JO-BOLT Fasteners.

National Products

THE NATIONAL SCREW & MFG. COMPANY
CLEVELAND 4, OHIO
California Division, Los Angeles 22

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ohm-cm. The Hall mobilities at 20 deg C are reported as 55 cm^2/V-sec for holes and one cm^2/V-sec for electrons.

The *Graphs* also show the optical characteristics of boron. Although opaque in the visible region, the material transmits considerable portions of the infrared spectrum and may be useful as a window for wavelengths from one to eight microns. The absorption coefficient is quite sensitive to purity. (It has been used as a measure of boron purity).

Boron is one of the hardest materials known (*Table II*). The modulus of elasticity of the amorphous form has been reported as 64×10^6 psi, while the strength ranges from 230,000 to 350,000 psi. Boron has also been observed to be quite flexible when deposited on a tungsten filament. Powder compacts of boron bonded with boron oxide have shown compressive strengths of 50,000 psi.

Plasticity was observed above 1200 deg C

Plasticity has been observed in boron at temperatures above 1200 deg C at which some creep of deposited boron has occurred during vapor-phase decomposition of BBr_3. However, researchers have had no success in attempts to deform boron at temperatures as high as 2000 deg C (just below the material's melting point). Because of boron's unusual hardness and the tendency of all its forms to transform to the extremely complex beta-rhombohedral on heating, any degree of fabricability for boron is unlikely.

Boron's oxidation has been studied in some detail. The material is reasonably oxidation-resistant in air up to 600 deg C. Between 600 and 1100 deg C, a protective coating of B_2O_3 forms and retards oxidation. In this range, amorphous boron shows a higher oxidation rate than crystalline boron. However, the oxidation rate is low enough in both forms at 1000-1100 deg C so that about 75 per cent of a small sample was still unoxidized after 24 hours at temperature.

Above about 100 deg C, vaporization of B_2O_3 occurs and a suboxide tentatively identified as B_6O or B_7O is formed. Above 100 deg C boron nitride forms, too. The oxidation rate is quite high in the 1300-1500-deg C range; at 2000 deg C, the reaction is self-sustaining.—End

FORECAST

Laboratories for space science at Martin are now studying and forecasting the physical, psychological, and biological factors that will affect man in space . . . another tremendously fascinating program which attracts persons with exceptional professional abilities. If you have these abilities, you are invited to communicate with N. M. Pagan, Director of Technical and Scientific Staffing (Dept. G-10) The Martin Company, P. O. Box 179, Denver 1, Colorado.

MARTIN
DENVER DIVISION

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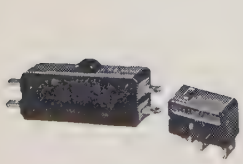
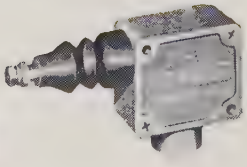
MAJOR MERGER IN SWITCH INDUSTRY

Controls Company of America Merges Hetherington Div. With Electrosnap Corp. to form New Control Switch Division.

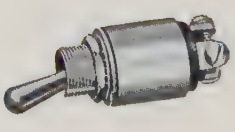
One of the precision switch industry's most complete product lines has come into existence with the announcement by Louis Putze, President of Controls Company of America, Schiller Park, Ill., that its subsidiary Hetherington, Inc., has been merged with Electrosnap Corporation, Chicago. The Electrosnap organization was recently merged with Controls Company of America. "This merger is important to switch users", Mr. Putze stated, "because it com-



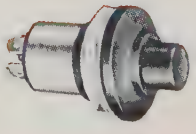
Basic Snap-Action Switches



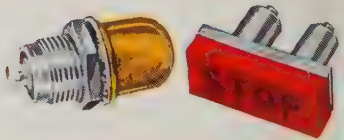
Limit Switches



Toggle Switches



Push-Button Switches



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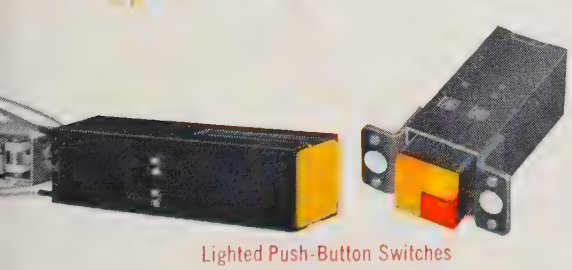
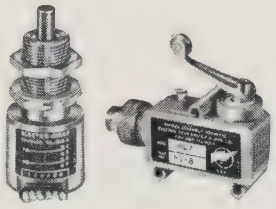
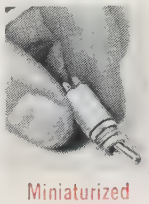


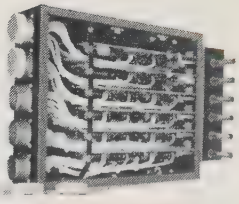
Lighted Push-Button Switches



Environment-Free and Hermetically-Sealed Switches



Miniaturized Switches



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Check Employment Inquiry Form on Page 211

Cheaper and lighter rockets with **filament winding**

With filament-wound rocket parts made of glass and resins, reports Rocketdyne, you can get strength-weight ratios that have never before been attained—and you get them at less weight and cost.

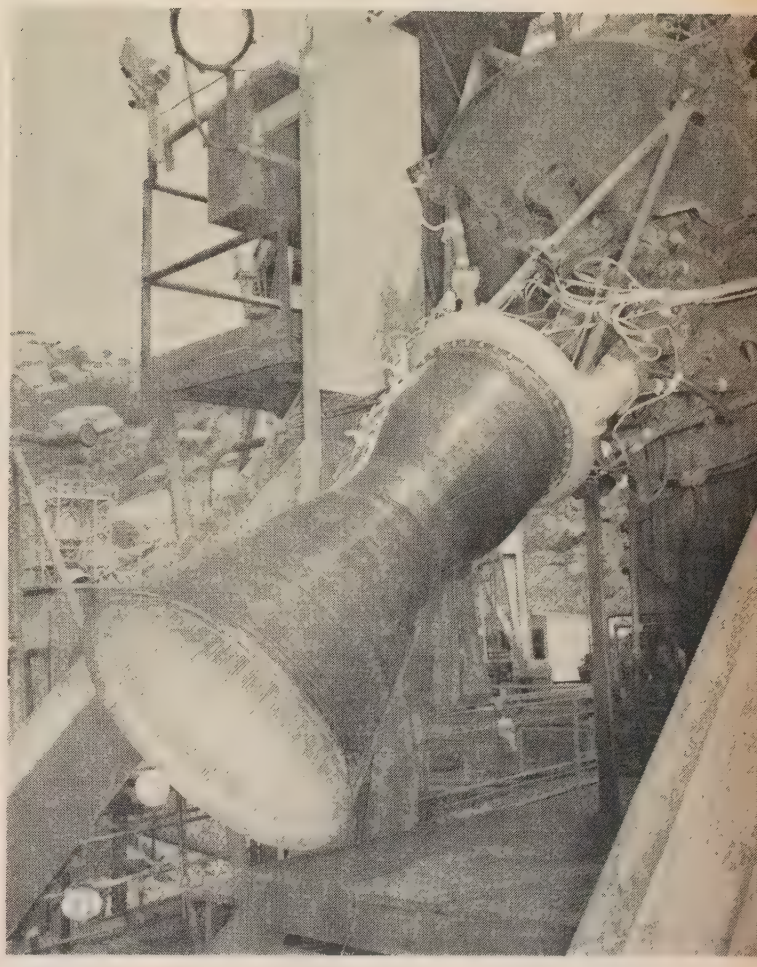
by Richard Gorcey, Supervisor,
Solid Propulsion Components, Rocketdyne Div.,
North American Aviation, Inc.

THE FIRST APPLICATIONS of filament winding at Rocketdyne grew out of 1952 studies on regeneratively cooled liquid propellant thrust chambers. These chambers were then being built by stacking up bundles of thin-wall tubing (shaped to the form of the chamber), silver-soldering them together, and at the same time silver-soldering steel bands around them. A second set of steel bands was welded over and between the first set so that the structure would carry lengthwise loads.

If this type of chamber could be completely encased in a shell of glass-reinforced plastic, we reasoned, the tubes would get the support they needed without the use of heavy bands and combustion gases would be stopped from escaping between the tubes without the use of silver solder. A 4500-lb thrust model chamber that had no silver solder and only a throat band was therefore covered with glass cloth and a phenolic resin by hand. This chamber wasn't a success, because at city water pressure the plastic shell was porous.

* Rocketdyne Div., North American Aviation, Inc., 6633 Canoga Ave., Canoga Park, Calif.

more on next page



FULL-SIZE 120,000-lb thrust liquid propellant thrust chamber of this type was filament-wound eight months after the start of a Rocketdyne development program.

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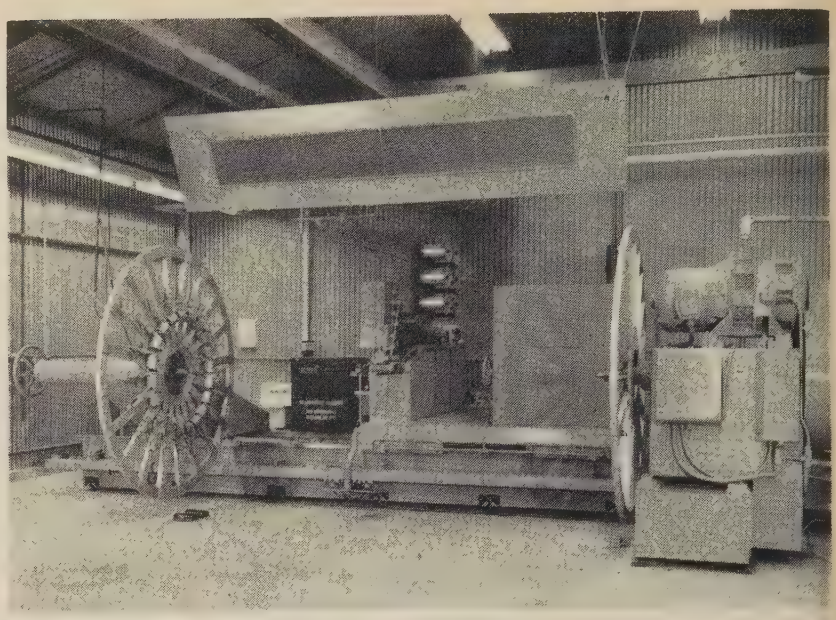

PERIPHERAL winding machine used for Atlas Boosters at Rocketdyne's Neosha, Mo., plant.

The fiberglass shell then was stripped and reapplied after two layers of rubber sheeting had been wrapped around the chamber and bonded in place. A polyester resin was then applied, because it proved easier to work with than the phenolic resin. The rubber stopped the leakage, but it took time to apply.

This second chamber was twice fired successfully at a pressure of 500 psi. After these tests in late 1954, we felt that the fiberglass shell was worth more detailed consideration. For one thing, we wanted to find some production process for the shell other than the relatively crude hand methods of the first two chambers. This goal led us to studies of forming by filament winding. Among the available reinforcing agents, glass had the greatest strength, so this material was chosen for our program —in a filament form known as "roving".

Peripheral winding preferred to helical

We concentrated our efforts on peripheral winding, in which all fibers are wound next to one another at an angle of about 90 deg to the axis of the part and which is simpler than helical winding, in which the fibers are wound at less

more on page 120

Physical Properties of Filament Winding and Metals

	Filament Winding				
	Type "E" Glass	High Modulus Glass	Titanium	Steel	Aluminum
Density (lb/cu in)	0.075	0.081	0.163	0.285	0.1
Tensile Yield Strength (psi)	120,000*	115,000	150,000	220,000	55,000
Strength-Weight Ratio	160×10^4	142×10^4	92×10^4	78×10^4	55×10^4
Modulus of Elasticity	5.5×10^6	9×10^6	16.5×10^6	30×10^6	10×10^6
Elongation (per cent)	2.18	1.28	0.91	0.73	0.55

* 220,000 psi unidirectional strength.

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This Stratofort flew half a million miles during the 00-hour test. Included were a 9,000-mile non-stop ght without refueling and a 13,000-mile non-stop fueled mission. At the conclusion of the test—conducted jointly by ARDC, SAC, and Boeing flight test personnel—the aircraft was "fine-tooth-combed" in inspection. According to Boeing, it was "sound as a thoroughbred."

Products of the Scintilla Division, the Bendix ignition systems, connectors, and cabling proved once more that there is no substitute for experience when it comes to delivering reliable, high-key performance such as required on the mighty B-52G.

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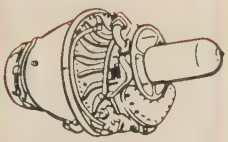

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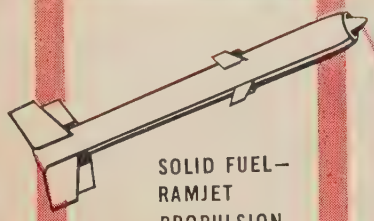
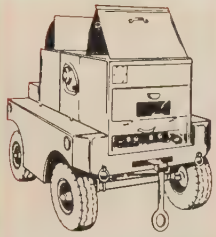


SOLID FUEL—
RAMJET
PROPULSION



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ROCKETDYNE solid propellant case produced by filament winding.

than 90 deg and cross one another. This type of winding is especially well suited to thrust chambers, whose imposed loads are mainly hoop stresses. You can thus take full advantage of the undirectional quality of the fiberglass roving. An epoxy resin was used in order to maintain the highest possible strength.

Machine was developed for peripheral winding

Our program had three aims:

- development of a winding machine,
- development of a production technique,
- optimization of the resin-glass combination.

The basic machine we developed for peripheral winding has five parts: a rack for holding the roving; a box that is filled with resin and through which the roving is drawn for impregnation; a squeezing device for removing excess resin; a feeding mechanism that carries the roving across the length of the part; and a rotating shaft on which the part to be wound is mounted. The main problem in developing the machine was to devise a mechanism that thoroughly impregnates the roving and removes the excess resin without shredding and breaking the roving.

The roving had to be kept from sliding

The big problem that we had to overcome in devising a production technique was how to keep the roving from sliding down the sloping sections of the chamber. The next headache involved gas leakage through the shell at high pressure. Our shell was leak-tight up to about 30-50 per cent of its burst strength, but at higher pressures some cracking occurred in the resin, which sometimes led to leak-

more on page 122

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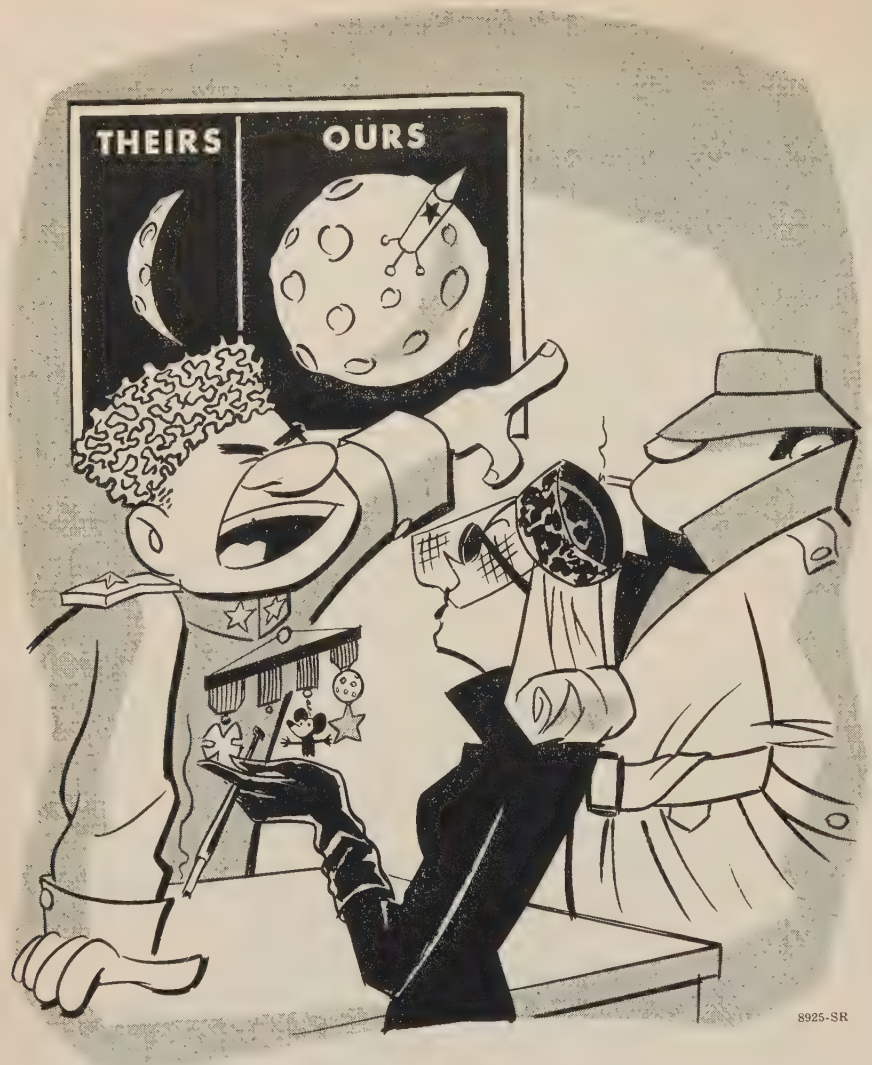

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age. To stop the leakage, we coated the chamber with a flexible resin that deforms with pressure rather than cracks.

An extensive test series was run to find the resin-glass combination with the best properties. The various rovings studied in these tests differed mainly in their size, a chemical treatment that affects the physical properties of the cured part.

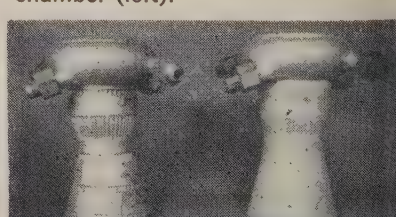
Actually our optimization studies went beyond the resin-glass combination and involved many other factors that could affect the strength of the part, like the heat treatments of the roving and the resin, the parts cure pressure, the laminate thickness, etc. Tests showed that, contrary to many previous opinions on the subject, it wasn't necessary to heat either roving or resin, that no pressure was needed during curing, and that no strength was lost with laminates of at least 1/4 in. thickness. These findings greatly simplified the entire winding operation. The resin-glass combination that we finally decided on has withstood average hoop stresses of 230,000 psi in tests of cylindrical, three-inch-ID specimens.

Hundreds of chambers have been wrapped

About five months after the start of this filament winding work, a 3000-lb thrust model motor was wrapped and fired successfully. Three months later, the first full-size 120,000-lb thrust chamber was wrapped. Since then, hundreds of chambers of varying sizes (up to exit diameters of about six feet) and thrust levels (up to 400,000 lb) have been successfully wrapped and fired. In all cases, filament winding provided excellent strength-weight ratios and substantially reduced the cost and weight of the chamber and the fabricating time. The reliability of filament winding has been shown in more than 1000 firings. One

more on page 126

ROCKETDYNE'S first successful plastic-enclosed thrust chamber (right) and a conventional silver-soldered chamber (left).



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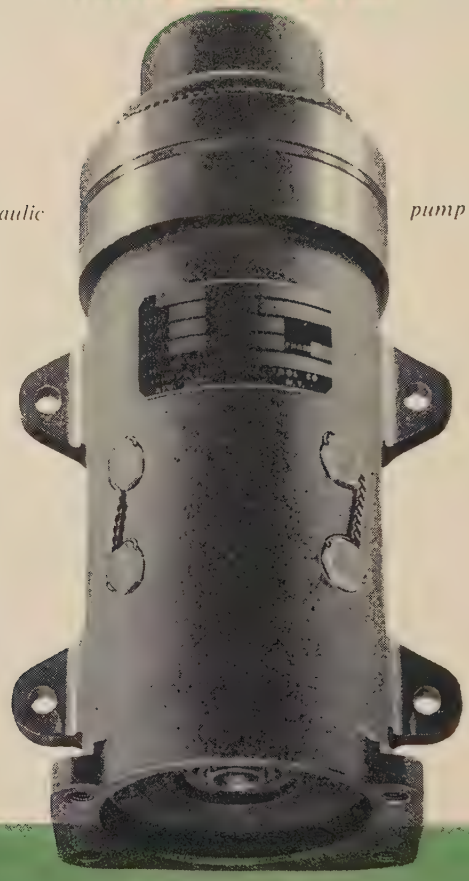

DC-86 Motor drives a hydraulic pump on the Polaris Missile.

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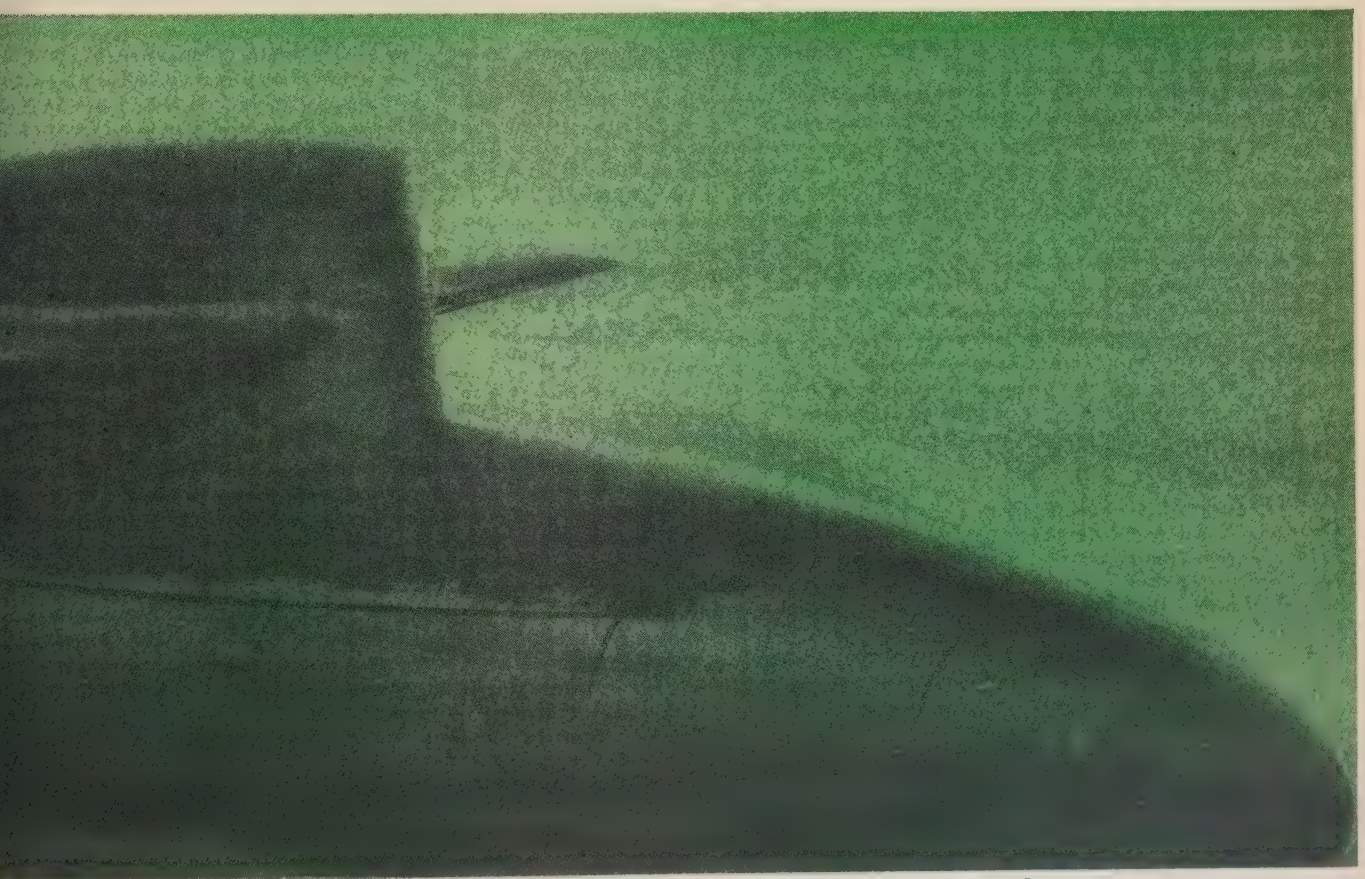

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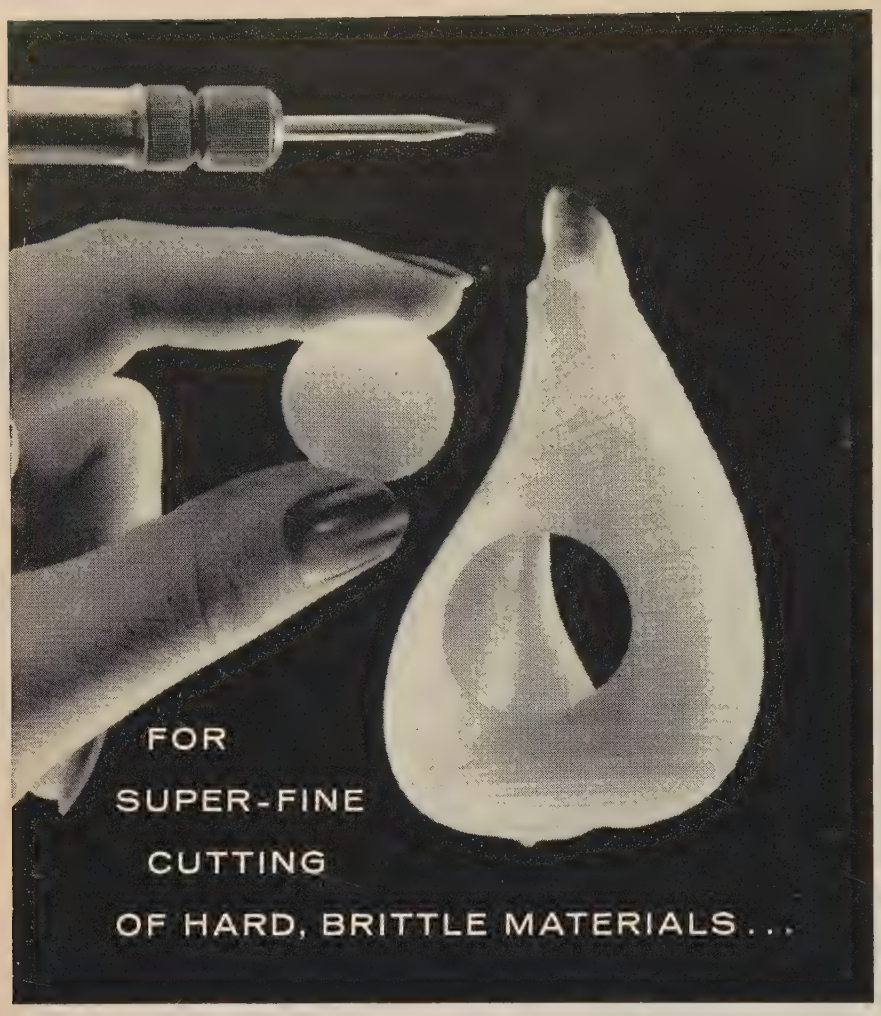

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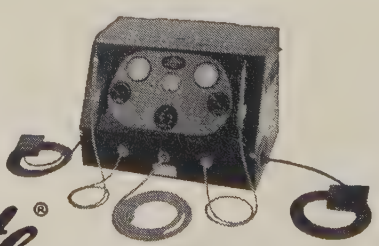

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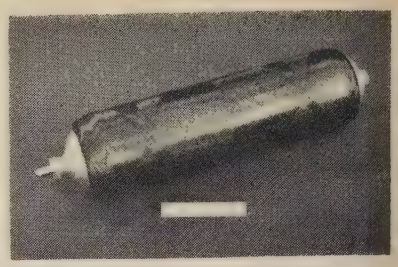

HELICALLY wound Rocketdyne test specimen.

150,000-lb thrust chamber, has chalked up 3500 seconds of firing time in 44 runs.

In our present filament winding operation for Atlas booster chamber, the first step is the sandblasting of the chamber area that is to be wound. This area then is coated with a thixotropic resin that gives a good bond between tubes and winding. Once this coating is oven-cured, the chamber is ready for winding.

Hoop stresses determine the number of layers

The number of layers that is wound depends on the hoop stresses imposed on the final shell. The layers sometimes are wound over lengthwise strips of glass roving. They are held together by a minimum of cross-fibers to give maximum strength in the longitudinal direction and take care of the lengthwise loading on the chamber that cannot be taken up by the peripherically wound filaments.

After enough material has been built up, attachments are bonded and wrapped in place. The whole assembly is then oven-cured.

More than 55 lb saved per Atlas chamber

Although the Atlas chambers are filament-wound only up to the throat area of the injector end, the weight saving per chamber is more than 55 lb. The cost reduction due to filament winding is about 25 per cent, and the fabrication time is cut from almost two weeks for steel-banding to two shifts. Still more weight could be saved if the safety factors were reduced to those of steel chamber, which are more than 50 per cent lower.

We are now working toward uncooled thrust chambers for both solid and liquid propellants. To

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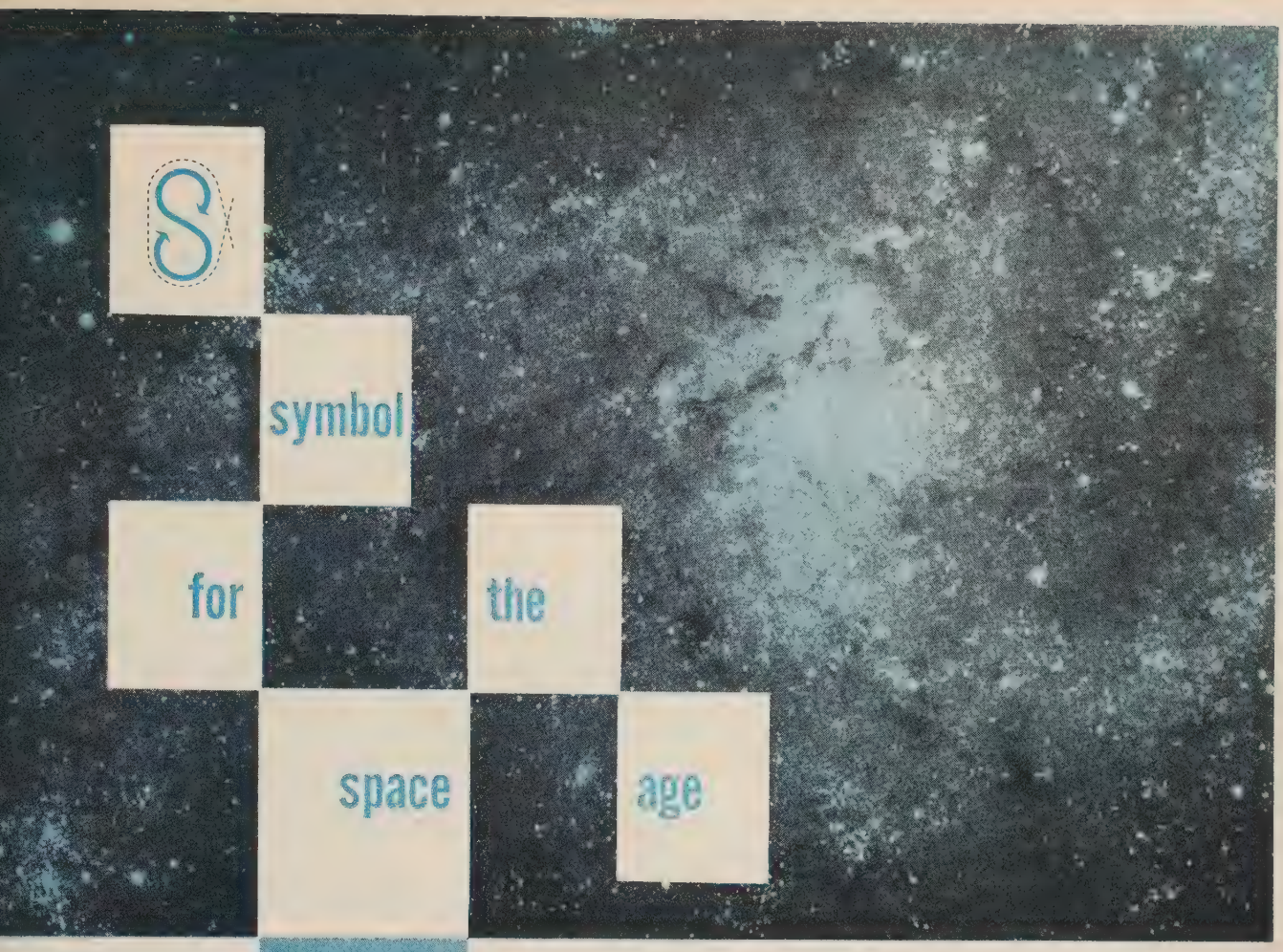

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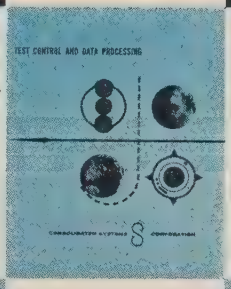

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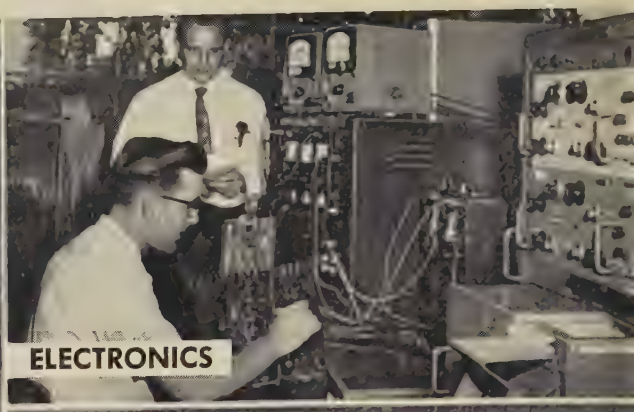

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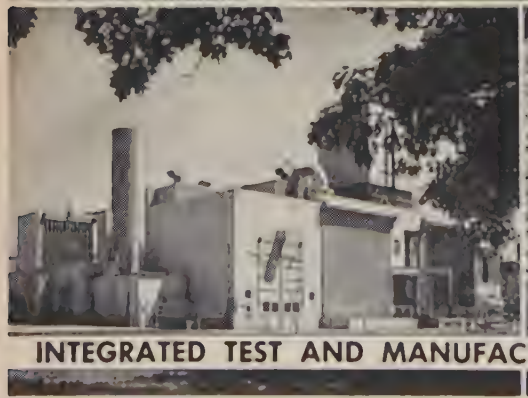

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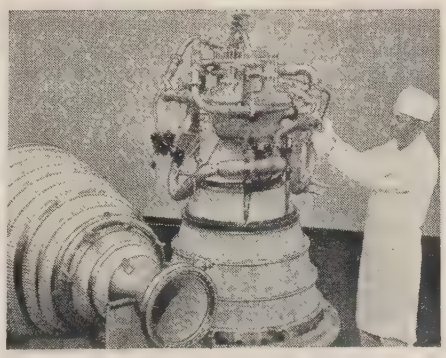

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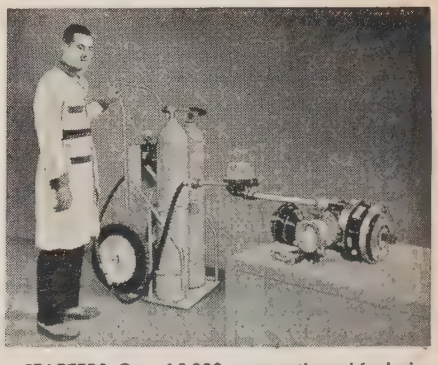

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withstand the high internal temperatures, a special reinforced-plastic liner is applied that ablates and resists erosion. This liner is then filament-wound on the outside for structural strength.

Filament winding lends itself very well to pressure vessels and propellant tanks, too. The basic materials and methods are the same in these applications as for thrust chambers, but there are also some differences. Above all, peripheral winding is no longer good enough, and helical winding must be used.

The end cap should not be kept in place

With peripheral winding, it proved impossible to keep the full-diameter end cap in place on highly pressurized vessels of large diameter. The trouble is that the shear load that a bonded cap joint can sustain increases at a lower rate than the length of the lap, and beyond certain lengths it does not increase at all. For a constant pressure, therefore, the load on the head increases as the square of the diameter, while beyond a certain length of bond the ability of the bond to withstand the load increases only as does the diameter.

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Helical winding attractive for large tanks

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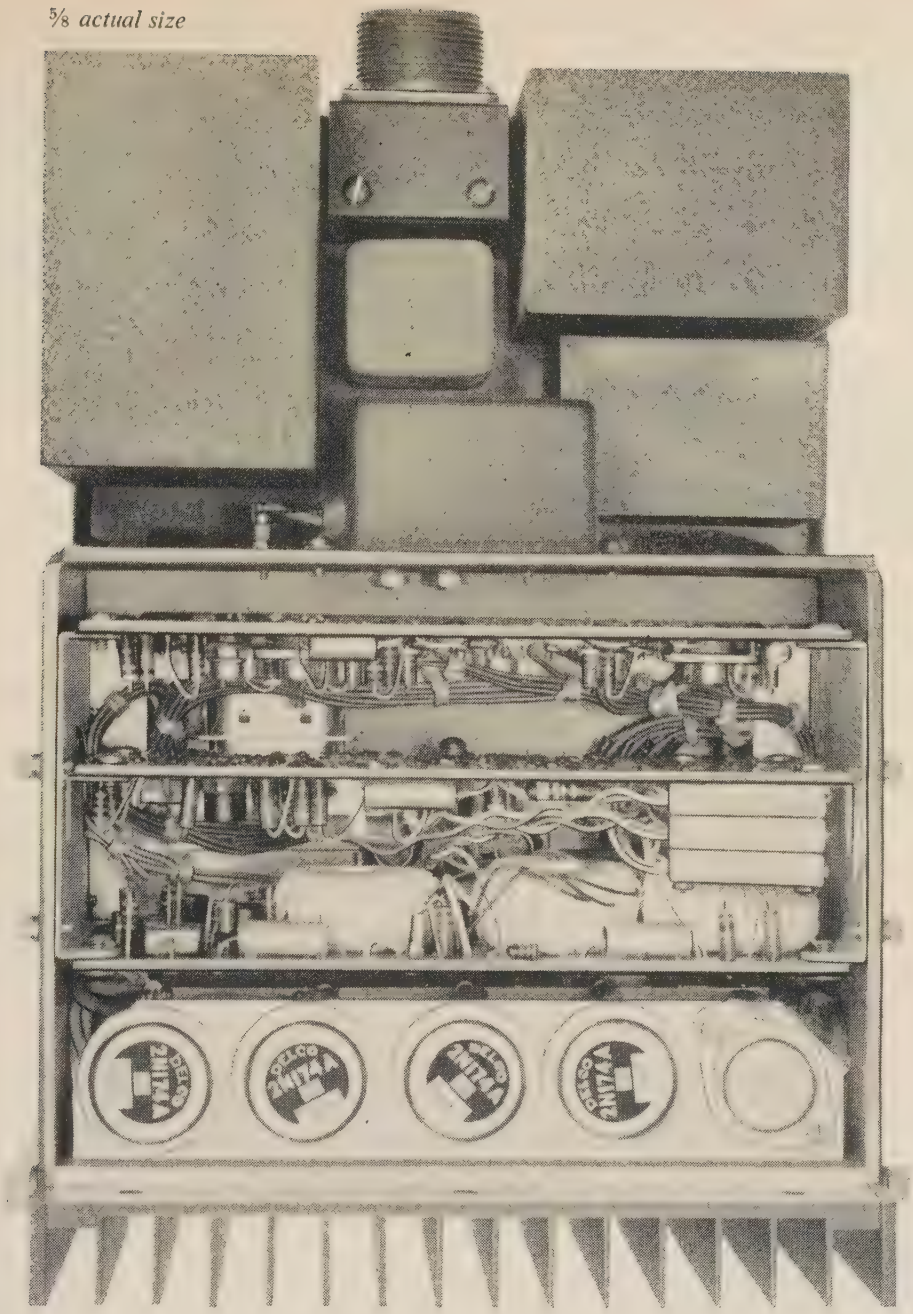
Since pressure vessels and liquid propellant tanks are very similar in shape and purpose to solid propellant cases, these obviously also are well suited to filament winding. Sometimes you can wind the nozzle

more on page 132

5/8 *actual size*



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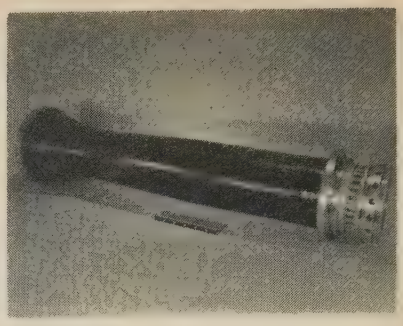

FILAMENT-WOUND 3000-lb thrust model motor similar to this one was wrapped and fired successfully without damage early in Rocketdyne's development program.

and case of a solid rocket as a single part and get rid of undesirable joints.

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A limited number of copies is still available on several recent SPACE/AERONAUTICS reprints:

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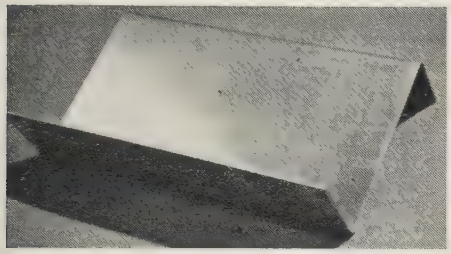

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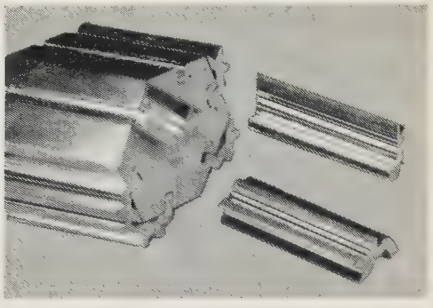

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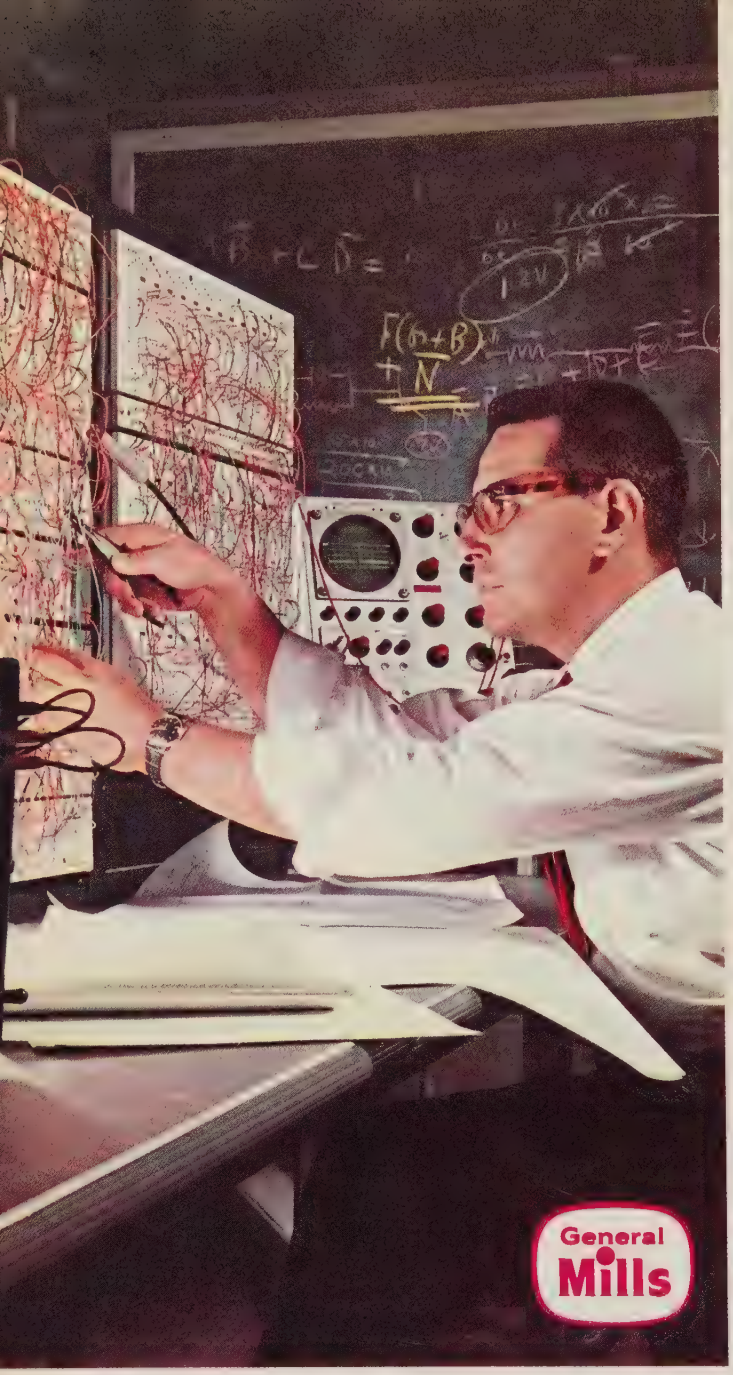

Here is Francis Alterman, Manager of General Mills Digital Computer Laboratory, checking one of our newest computers which he helped design. General Mills computers, both analog and digital, are being used in missile guidance, bombing and navigation systems, automatic surveying and in industrial control. In future space travel, computers will help control navigational systems of space vehicles and will process data gathered in outer space.

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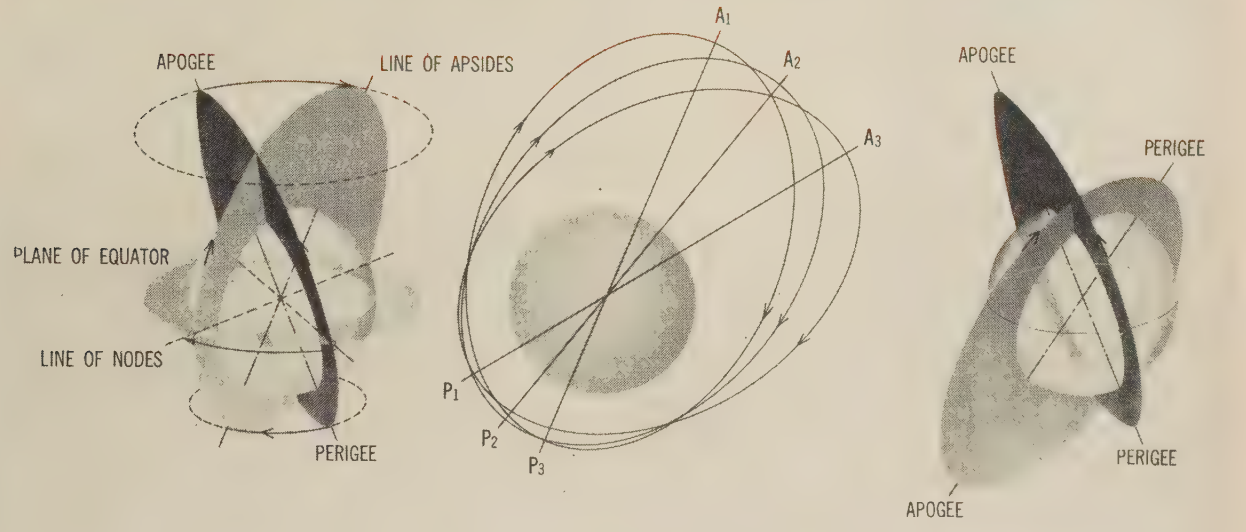


BECAUSE the earth is oblate, a satellite does not describe a true ellipse. The ascending node of its orbit has a westward secular motion (left) and there is also a motion of the line of apsides (center). These two effects combine in a motion (right) that produces the imperfect ellipse that the satellite actually describes.

Finding the oblateness effects on satellite orbits

That orbit mechanics would be much easier if only the earth were really round has been repeated ad nauseam—but that doesn't make the statement any less true. A lot of problems arise, for instance, when you try to figure the distortions of the imperfect ellipse that a satellite describes because the earth isn't a golf ball. Here is a new approach to this calculation that does away again with many of these headaches.

by Englebert Kirchner, Managing Editor

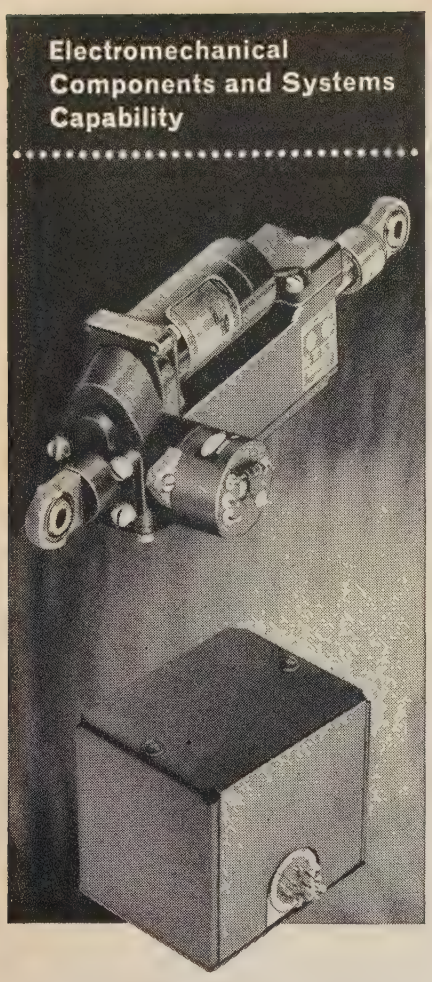
IN A single passage, an artificial earth satellite describes approximately an ellipse. If the earth were a true sphere, the satellite's orbit would be a true ellipse (relative to an inertial frame of reference and provided the perigree is high enough and the apogee low enough so that drag and the moon's action can be neglected).

The orbital ellipse is imperfect because the earth is oblate, or flattened at the poles. The orbit's ascending node has a westward secular motion of 3-4 deg per day as well as a small periodic motion. The earth's oblateness also causes a motion of the line of apsides (the major axis of the "ellipse") relative to the line of nodes (which leads from the center of the earth to the ascending node).

To determine these oblateness effects in detail, you normally had to apply perturbation theory, starting either with an unperturbed orbit corresponding to true spherical symmetry or with an "intermediate"

more on next page

Electromechanical Components and Systems Capability



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orbit. The latter orbit can be found exactly in terms of quadratures, but it allows only partly for the effects of oblateness and corresponds to a gravitational potential that does not satisfy Laplace's equation.

In a program funded by the Air Force, the National Bureau of Standards, Washington 25, D.C., developed a simpler method for finding the effects of the earth's oblateness. The final results of this program are still being worked out, but it is already clear that the new method gets rid of many of the problems involved in applying perturbation theory. It can even be used when the orbital inclination approaches the critical value of 63.4 deg, a case in which special considerations might otherwise have to be applied.

Geometrical symmetry of problem is used

The NBS method applies for satellite orbits for which drag is negligible and is based on an analysis by John P. Vinti, of the Bureau's Mathematical Physics Group.[1] It relies on oblate spheroidal coordinates to take advantage of the geometrical symmetry of the problem and requires you to find the most general solution of Laplace's equation (non-singular outside the earth). Used as a gravitational potential, this solution makes the Hamilton-Jacobi equation separable.

Vinti starts his analysis—which applies for any satellite orbit close enough to a planet so that the forces of other heavenly bodies can be neglected—by considering the earth as an axially symmetrical, oblate planet. The gravitational potential outside the earth then is:

$$(1) \qquad V = -\mu r^{-1}\left[1 - \sum_{n=1}^{\infty} J_n (R/r)^n P_n(\sin\theta)\right],$$

where μ is the product of the gravitational constant and the earth's mass (M); r, the distance from some point O on the earth's axis of symmetry (or polar axis) to the satellite and identical with $|\mathbf{r}|$, O being the "center", or origin, of a coordinate system and $\mathbf{r}$ the corresponding position vector of a field point; R, the equatorial radius, or the radius of a section through O that is normal to the polar axis; θ, the declination, or the complement of the angle between $\mathbf{r}$ and the polar axis; and J_n and $P_n(\sin\theta)$ denote the coefficients of the harmonics[2] and the Legendre polynomials, respectively. J_2 is given by:

$$(2) \quad J_2 = 2J/3 = (I_p - I_t)/MR^2,$$

where J is a quantity introduced by Jeffrey's[3] and I_p and I_t are the planet's moments of inertia about the polar and transverse axes.

Vinti goes on to define his oblate spheroidal coordinates (ξ, η, ϕ) by:

$$(3) \quad x = c[(\xi^2 + 1)(1 - \eta^2)]^{\frac{1}{2}} \cos\phi \qquad (0 < \xi < \infty),$$

$$y = c[(\xi^2 + 1)(1 - \eta^2)]^{\frac{1}{2}} \sin\phi \qquad (-1 \leq \eta \leq 1),$$

$$z = c\xi\eta,$$

(1) "New Method of Solution for Unretarded Satellite Orbits;" *J. Res. NBS*, 62B/2 ('59).

(2) R. H. Merson & D. G. King-Hele, *Nature*, 182/640 ('58).

(3) H. Jeffreys, "The Earth", 3rd ed.; Cambridge U. Press ('52).

more on page 140

Amplitudes of Even Harmonics

Source	Harmonic (Zeroth)10^6	$-10^6 J_2$	$-10^6 J_4$	$-10^6 J_6$
Jeffreys	10^6	−1090	2.45	
From fit of b_0 and c to Jeffreys' J	10^6	−1090	1.19	-1.3×10^{-3}
King-Hele and Merson	10^6	−1080	1.37 ± 0.23	-0.1 ± 1.5
From fit of b_0 and c to King-Hele's and Merson's J	10^6	−1080	1.17	-1.26×10^{-3}

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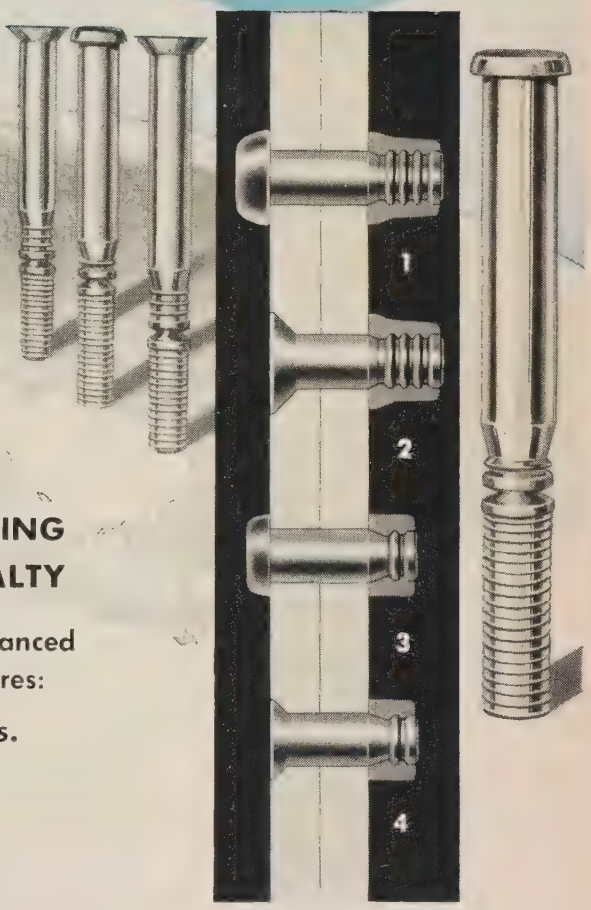

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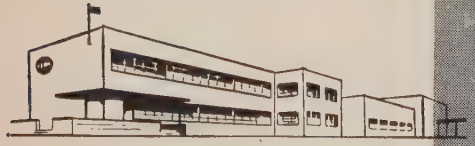

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where c is a constant distance that can be adjusted to make the solution of Laplace's equation agree rather well with the earth's potential (as known empirically).[4]

The Hamilton-Jacobi equation is written by Vinti in the form:

$$(4)\quad (\xi^2+1)\left(\partial S/\partial\xi\right)^2+(1-\eta^2)\left(\partial S/\partial\eta\right)^2+[(\xi^2+\eta^2)/(\xi^2+1)(1-\eta^2)]\left(\partial S/\partial\phi\right)^2+2c^2(\xi^2+\eta^2)V(\xi,\eta)=2c^2(\xi^2+\eta^2)\alpha_1,$$

where $\partial S/\partial\xi$, $\partial S/\partial\eta$, and $\partial S/\partial\phi$ are the generalized momenta $S(\xi, \eta, \phi)$ being the action function, and α_1 is the constant energy. To separate the variables in *Equation 4*, we express S as:

$$(5)\quad S=S_1(\xi)+S_2(\eta)+S_3(\phi).$$

Now *Equation 4* becomes:

$$(6)\quad (\xi^2+1)S_1'^2+[(1-\eta^2)S_2'^2+[1/(1-\eta^2)-1/(\xi^2+1)]S_3'^2+2c^2(\xi^2+\eta^2)V(\xi,\eta)=2c^2(\xi^2+\eta^2)\alpha_1,$$

where S_1', S_2', and S_3' equal $dS_1/d\xi$, $dS_2/d\eta$, *and* $dS_3/d\phi$, respectively.

From *Equation 6* it follows that $S_3'^2$ can be expressed as a function of ξ and η alone, so that we get:

$$(7)\qquad S_3'=\alpha_3=constant$$

We further see from *Equation 6* that ξ and η can be separated in only one case—if the potential has the form:

$$(8)\quad V(\xi,\eta)=(\xi^2+\eta^2)^{-1}[f(\xi)+g(\eta)].$$

Can we find a solution of Laplace's equation of the form of *Equation 8* that adequately represents the even harmonics in the earth's potential? Essentially yes, according to Vinti.

For the case of axial symmetry, Vinti writes Laplace's equation in oblate spheroidal coordinates as:

$$(9)\quad \partial/\partial\xi[(\xi^2+1)\partial V/\partial\xi]+\partial/\partial\eta[(1-\eta^2)\partial V/\partial\eta]=0.$$

In a process involving some 20 further equations, Vinty solves this equation so that the Hamilton-Jacobi equation becomes separable:

$$(10)\quad V=(\xi^2+\eta^2)^{-1}(b_0\xi-b_1\eta)=b_0Re(\xi+i\eta)^{-1}+b_1Im(\xi+i\eta)^{-1}.$$

This solution contains two explicit adjustable constants (b_0 and b_1) as well as an implicit adjustable constant (c), which we have already used in the equations of transformation from oblate spheroidal to rectangular coordinates. Since the expression $(\xi+i\eta)^{-1}$ is clearly a solution of *Equation 9*, *Equation 10* must be a solution, too.

(4) P. M. Morse & H. Feshbach, "Methods of Theoretical Physics," vol. 1 & 2; McGraw-Hill ('53).

more on page 142

TYPICAL ELECTRIC BLANKET. This is a HITCO "form-fitting" Blanket used to control temperature of hydrogen peroxide tank.

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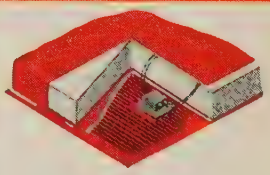
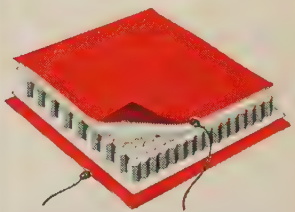


CUTAWAY VIEW. Shows Heating Element of HITCO Electric Blanket—sealed between cover and inner cover.



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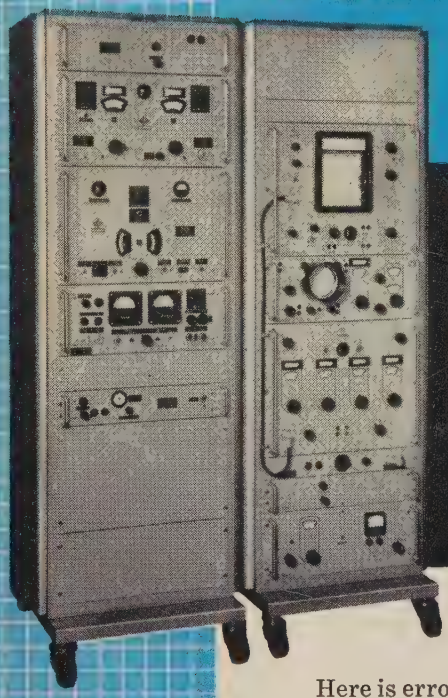

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The implicit adjustable constant becomes explicit in the expansion of the potential in spherical harmonics, which ultimately yields:

$$(11)\quad V = b_0 c r^{-1}\,[1 - c^2 r^{-2} P_2(\sin\theta) + c^4 r^{-4} P_4(\sin\theta) - \ldots] - b_1 c r^{-1}\,[c r^{-1} P_1(\sin\theta) - c^3 r^{-3} P_3(\sin\theta) + \ldots].$$

If we compare *Equations 11 & 1*, we see that, to fit the zeroth, first, and second harmonics, we must choose, respectively:

$$(12)\quad b_0 c = -\mu, \quad b_1 c^2 = -\mu R J_1 = \mu\delta, \quad c^2 = R^2 J_2,$$

where J_1 equals $-\delta/R$, δ being the northerly displacement of the center of mass from O. The higher harmonics are now all fixed (as can be shown by relationships derived from *Equation 11*).

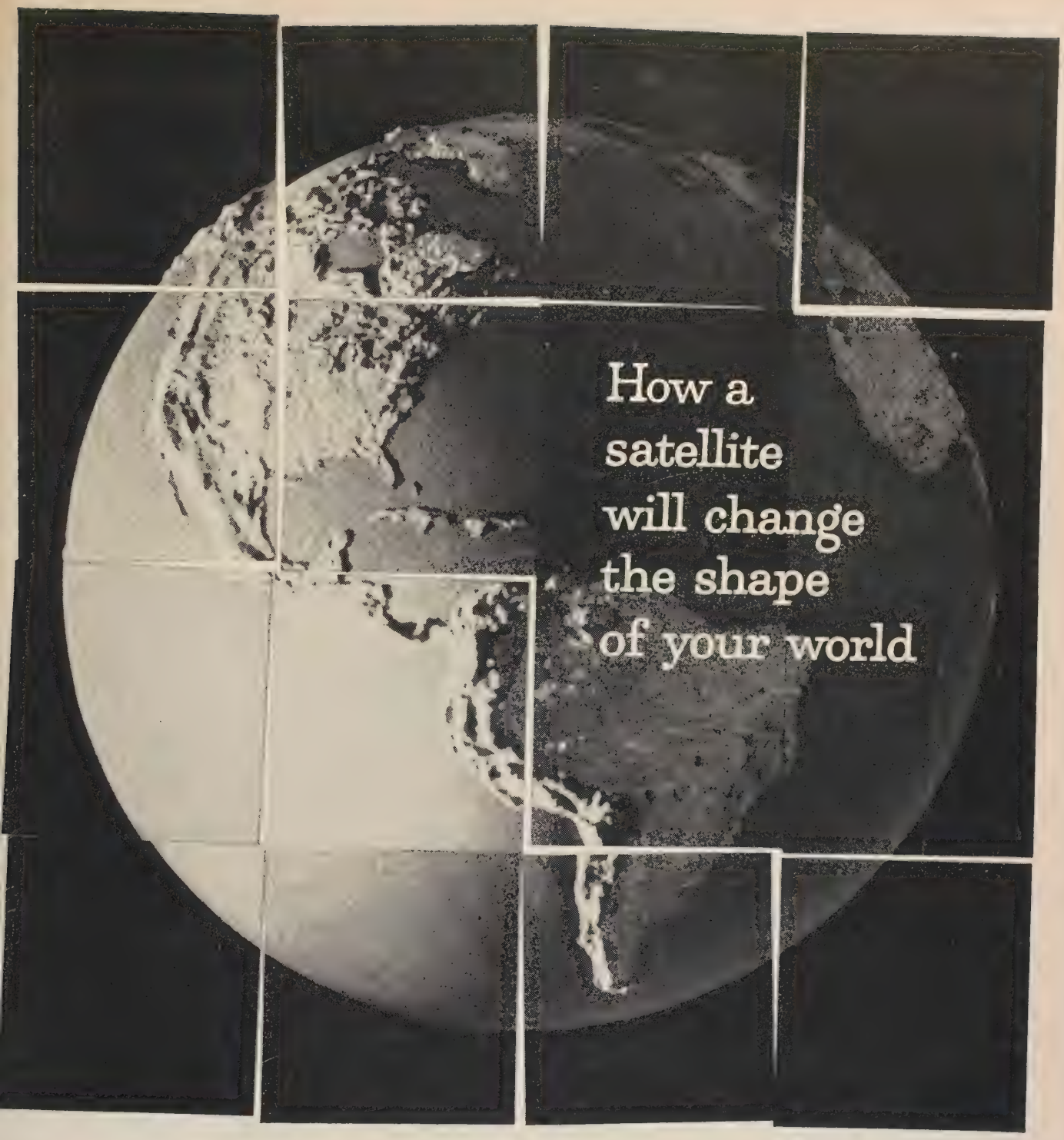
As a result of the choices expressed in *Equations 12*, the potential takes the form:

$$(13)\quad V = -\mu r^{-1}\,[1 - J_2 (R/r)^2 P_2(\sin\theta) + J_2^2 (R/r)^4 P_4(\sin\theta) - J_2^3 (R/r)^6 P_6(\sin\theta) + \ldots] - J_1 (R/r) P_1(\sin\theta) + J_1 J_2 (R/r)^3 P_3(\sin\theta) - J_1 J_2^2 (R/r^5 P_5(\sin\theta) + \ldots].$$

To get an idea of how adequate this equation is, let's compare the amplitudes of the even harmonics it provides with the observed values reported by Jeffreys and King-Hele and Merson (see *Table*).[5] The fit of the zeroth and second harmonics necessarily is exact. Fitting to Jeffreys' J for the fourth harmonic produces an amplitude that amounts to 49 per cent of that given by Jeffreys. The resulting error of *Equation 13* comes to 1.26 parts per million, or 1.26 parts per 1100 for the oblateness potential. The amplitude we get for the fourth harmonic by fitting to King-Hele's and Merson's J amounts to 86±16 per cent of the observed value, so that the fitted harmonic in this case lies within the error limits of what appears to be the most reliable observation we have so far. The same holds true for the sixth harmonic. (King-Hele's and Merson's estimates for the sixth harmonic admittedly are hazy, but in any case

(5) Jeffreys, *op. cit.* King-Hele & Merson, *Nature*, 183/881 ('59). J. A. O'Keefe, A. Eckels, and R. K. Squires more recently have reported a value for the fourth harmonic that does not appear to be compatible with that given by King-Hele and Merson (see *Astron. J.* 65/245). Since the latter is based on an analysis of the observed nodal motions of two satellites, however, it is likely to be more accurate than the former, which is based on an analysis of the nodal and perigee motions of only a single satellite.

more on page 144



How a satellite will change the shape of your world

The "Doubting Thomas" who questions the practical value of today's space shots is answered by a growing list of useful satellites...

Just as a military need for radar helped you have TV sooner, so you can expect peacetime benefits to come from rocket and missile research.

Space probes have already revised our concept of Mother Earth's figure. Now geographers suggest maps made by camera from a cartographic satellite. It would give us the first completely accurate map of the world—a project of major value in defense.

While the map-making satellite is still to come, a rocket that can orbit it—the Douglas *Thor*—is already called "workhorse of the Space Age." It has been successful in more than 90% of its firings. It boosted the first nose cone recovered at ICBM range, and is already deployed at NATO sites abroad. Now the Douglas *Delta*, NASA's advanced research version of *Thor*, is ready to probe even deeper into space.

A series of satellites which will add to our knowledge of the world we live in are going into orbit. A major role in this research goes to the Douglas *Delta*, a research version of *Thor*.

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the error from *Equation 13* is only 0.2 part per million, or one part in 5500 for the oblateness potential.)

From *Equation 12* and the *Table* and for an equatorial radius *(R)* of 6378.388 km, we get 210.7 or 209.9 km for *c*, depending on whether we use the values given by Jeffreys or those given by King-Hele and Merson. Vinti points out that, contrary to the impression given by *Equations 3*, *c* is not so important that its accuracy would strongly affect numercial predictions. Actually, he points out, its value must be known only if you want to find the deviations of the orbit from a conic section.

Proceeding from *Equations 10 & 12*, Vinti also derives a working expression for V in oblate spheroidal coordinates:

(14) $V = -\mu c^{-1} (\xi^2 + \eta^2)^{-1} (\xi + \eta\delta/c)$.

By inserting *Equations 7 & 14* in *Equation 6*, he then gets the fully separated Hamilton-Jacobi equation:

(15) $(\xi^2 + 1) S_1'^2 - (\xi^2 + 1)^{-1} \alpha_3^2 - 2\mu c\xi - 2\alpha_1 c^2 \xi^2 = -(1 - \eta^2) S_2'^2 - (1 - \eta^2)^{-1} \alpha_3^2 + 2\mu\delta\eta + 2\alpha_1 c^2 \eta^2 = k$,

where k is a separation constant equal to each side of the equation.

Perturbation theory reduced in any case

Vinti sums up the results of his analysis by pointing out that the potential function he has developed is much closer to the actual potential at any point in space than any other function ever used as the starting point for calculating the effects of the earth's oblateness. If the results given by King-Hele and Merson are confirmed, he points out, his new function may allow us to do orbit theory for unretarded satellites very accurately without perturbations of the solution of the Hamilton-Jacobi equation. Even if those results aren't confirmed, there is still a good chance of minimizing the use of perturbation theory by distributing over the zeroth and second harmonics the secular effects of the fraction of the fourth harmonic that is not accounted for.

NBS also notes that the "intermediate" orbit corresponding to Vinti's solution (again found exactly in terms of quadratures) allows so accurately for oblateness that it may be taken as very close to a final orbit so far as even harmonics are concerned.—End

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*ATLAS—The Story of a Missile
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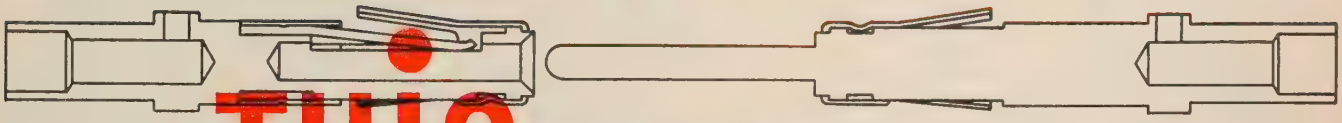

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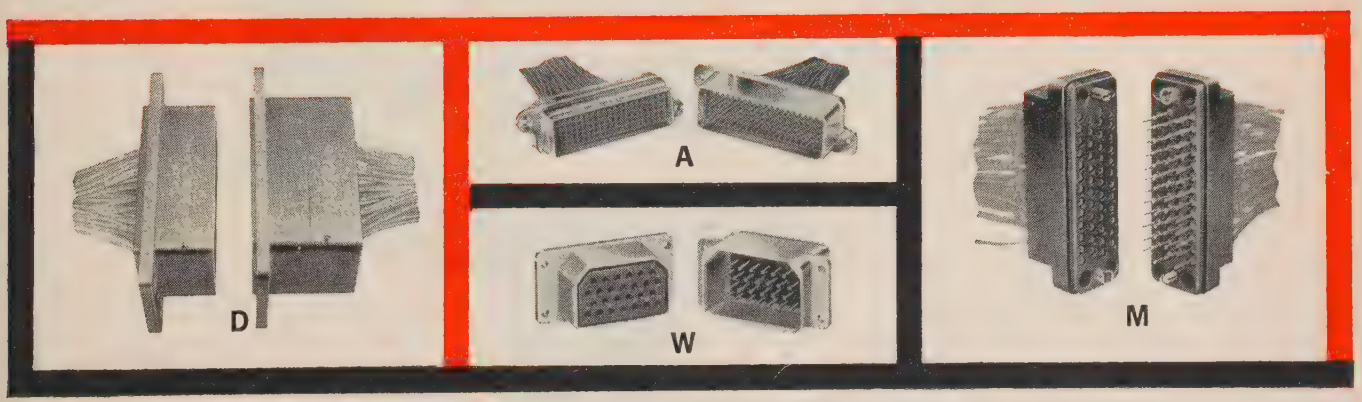

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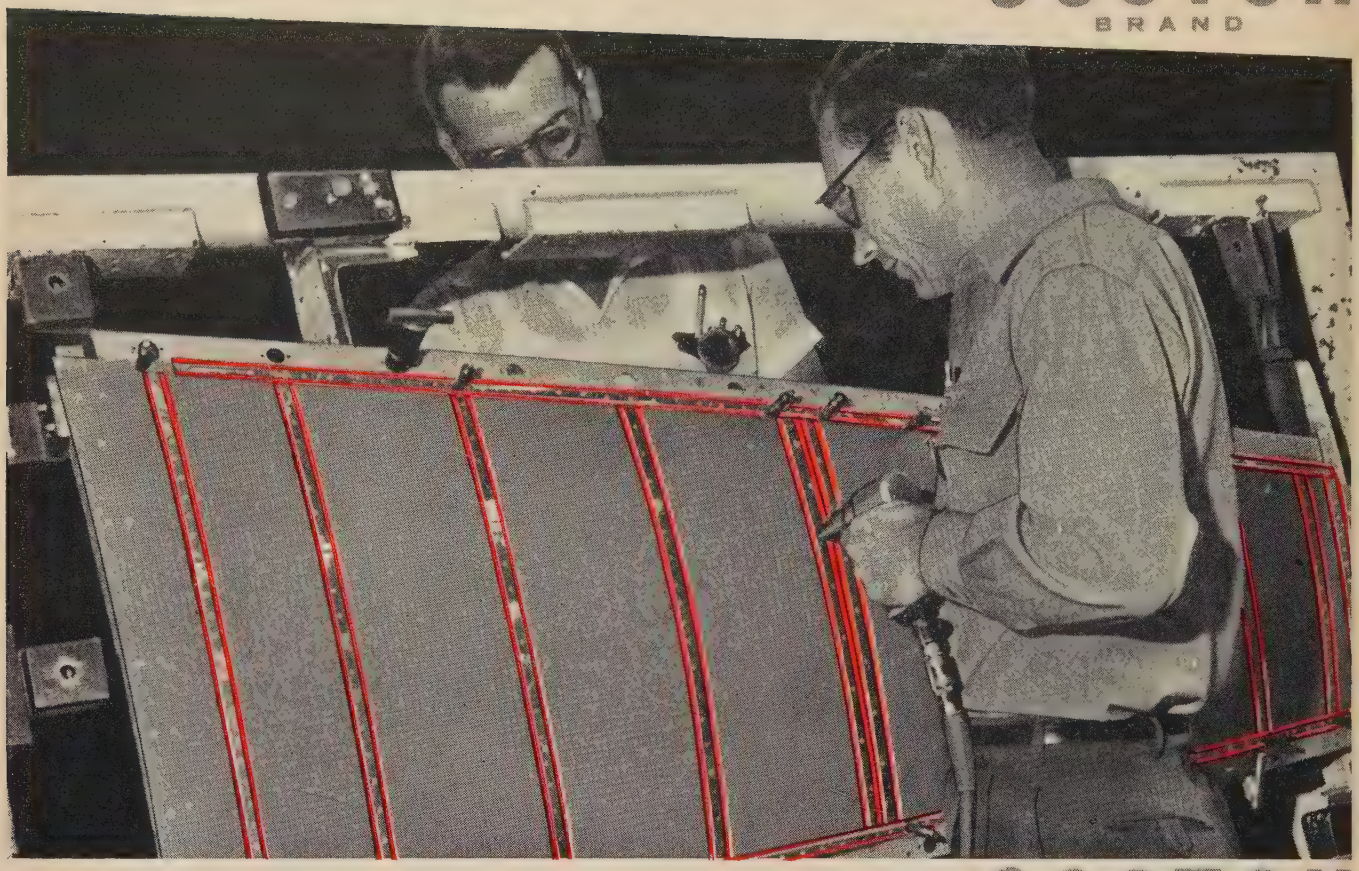

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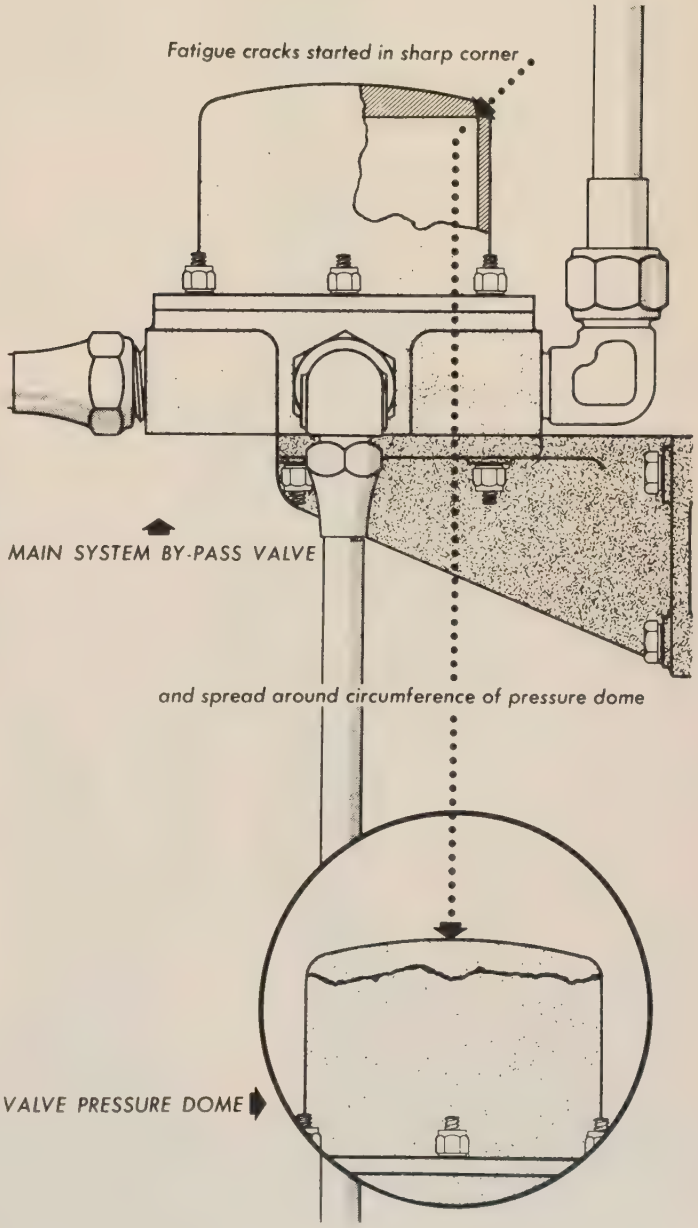
Poorly designed valves burst under pressure

FAILURE of the main hydraulic system bypass valves has caused sudden, complete loss of power with which to lower the landing gear and control the wing flaps. In two separate instances, Flight Safety Foundation, Inc., 468 Fourth Ave., New York 16, N.Y., reported, the valve's surge chambers blew their tops and sprayed the wheel wells with hydraulic fiuid.

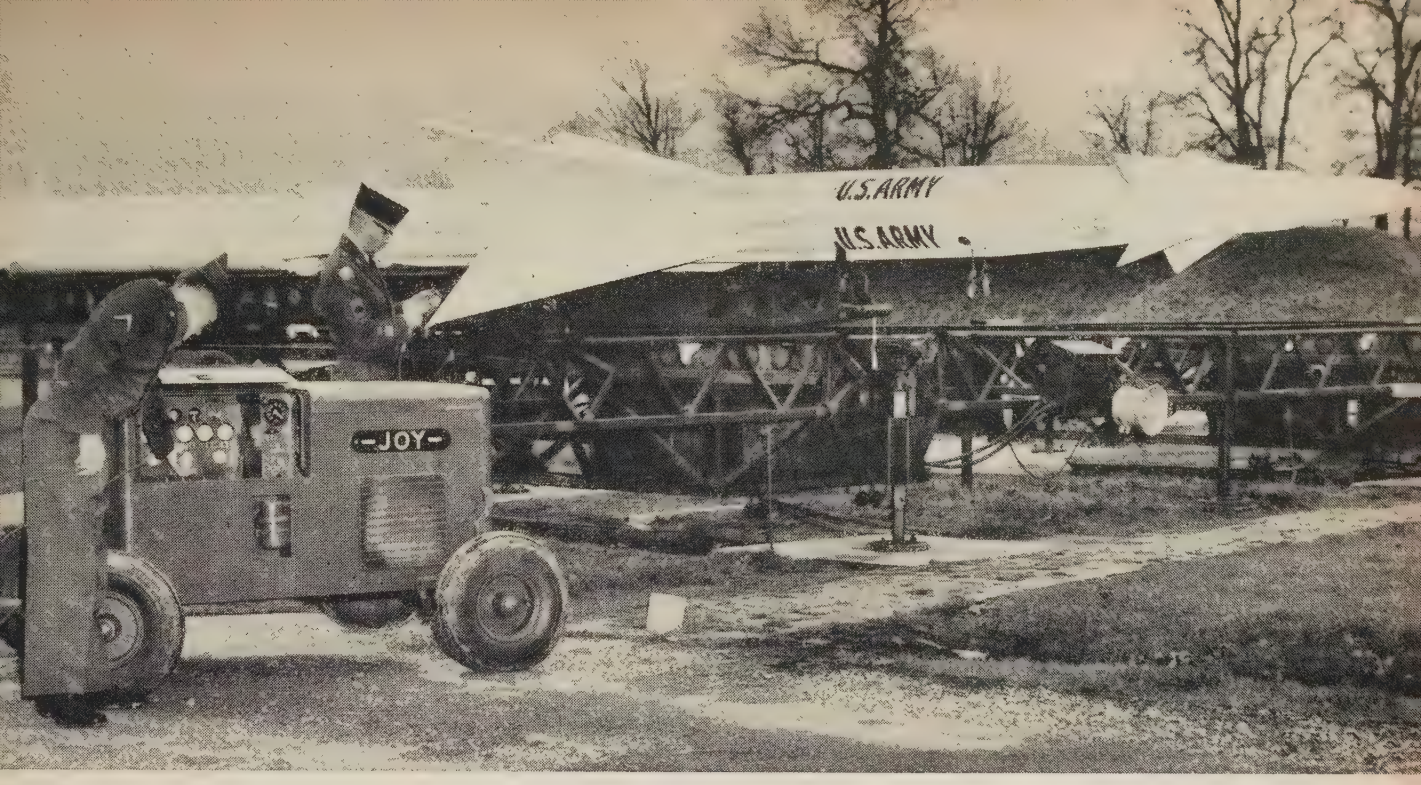

Fatigue cracks started in sharp corner
MAIN SYSTEM BY-PASS VALVE
and spread around circumference of pressure dome
VALVE PRESSURE DOME

The Hazard

Evidently the pressure domes were not designed to the extremely high loads to which they are subjected each time 3000 psi pressure is applied to the system, Flight Safety Foundation says. Instead of being designed with stress-relieving radii, the inside of the domes had sharp corners.

As a result, fatigue cracks started and spread until the domes could not withstand the pressure and burst.

Joy 80 HES compressor—supplies 5200 psi to pressurize the U.S.A.F. Bomarc before flight.



The gasoline-driven 15HGP Compressor primes the hydraulic system of the Nike-Ajax with air at 3500-4500 psi.

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oy high pressure compressors, providing 4000 psi air for pressurizing issiles, are in the hands of troops at scores of bases across the country. These re the same basic compressors which have been in service for years at air bases, nd aboard ship, for jet engine starting. Joy compressors with capabilities up to 000 psi are currently being supplied to missile contractors. These compressors re furnished with either gasoline or electric drives, and can be mounted on skids r wheeled carts.

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Model AVR70-D1134 high pressure fan is used on guidance system and GSE of Nike-Hercules.

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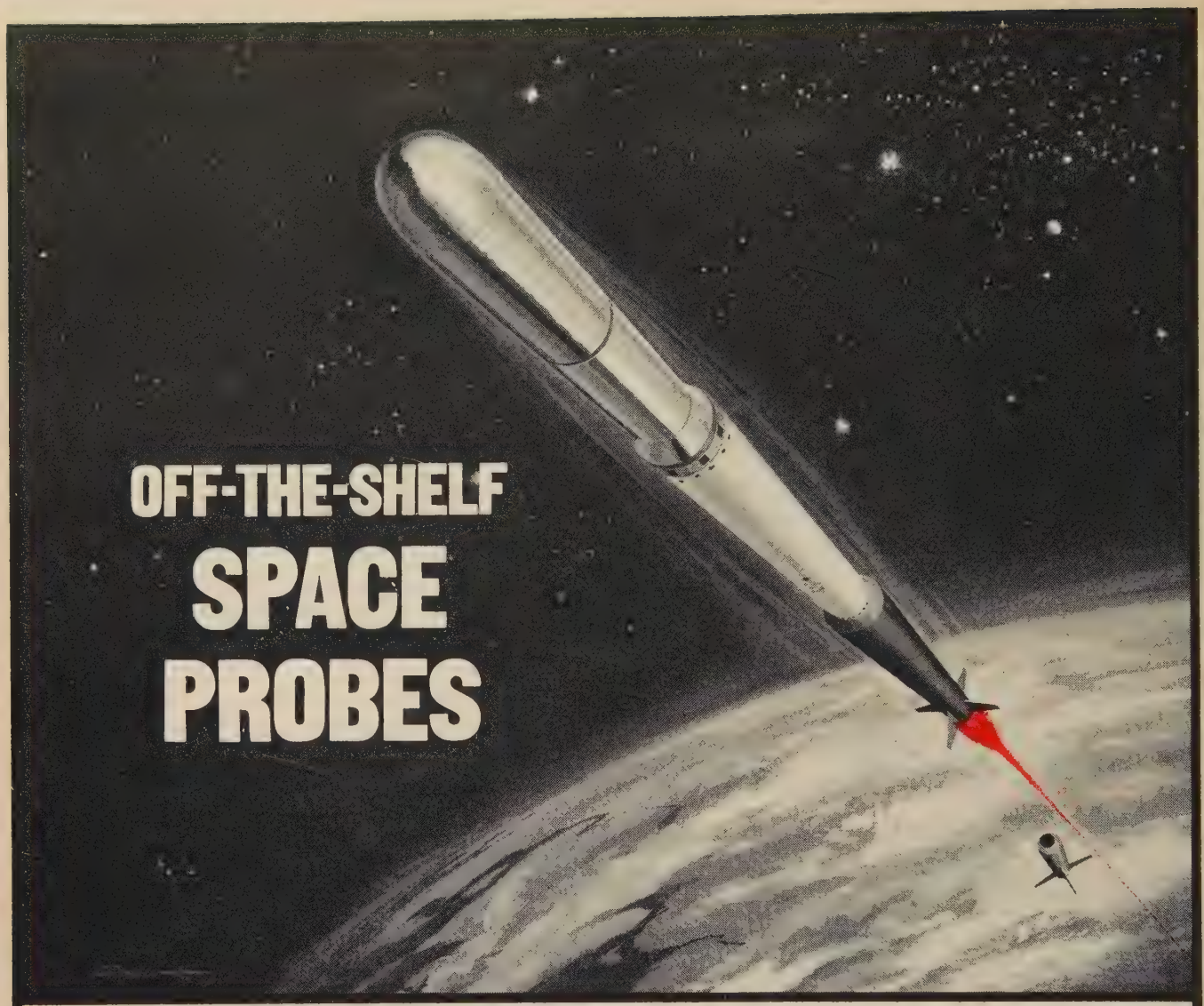

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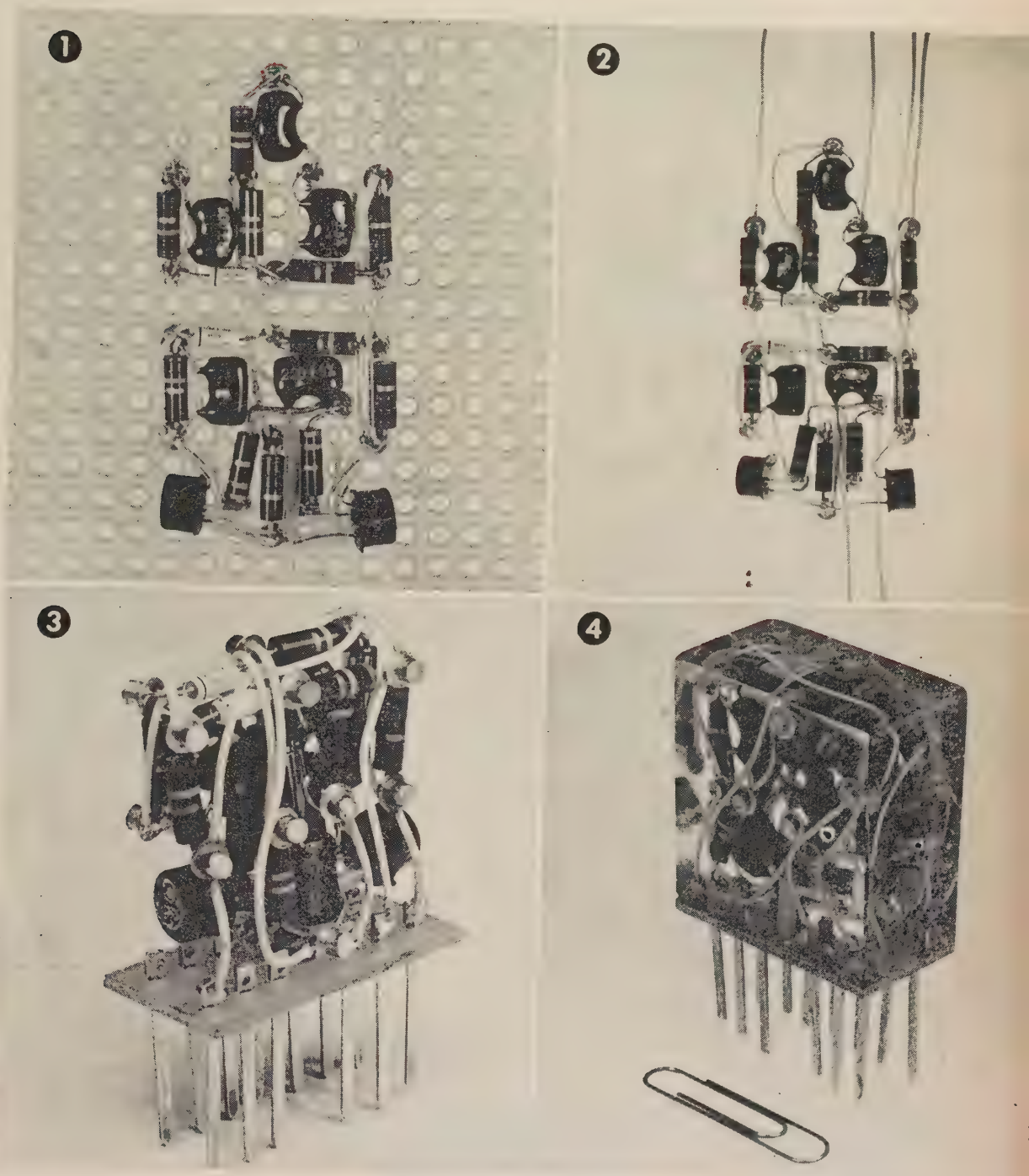
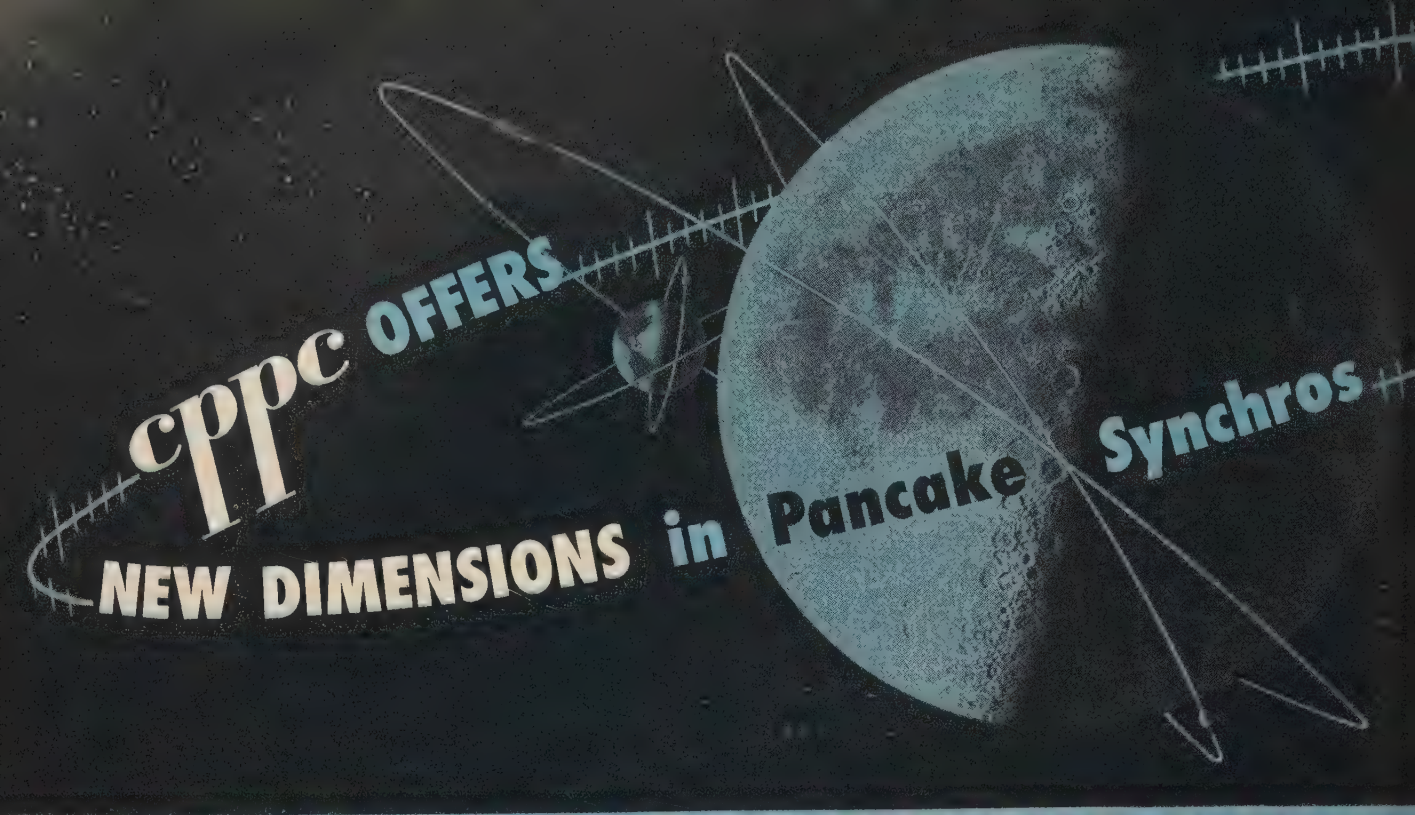


Grid-module method of assembling components for encapsulation is simple, cheap, easy to control, betters reliability



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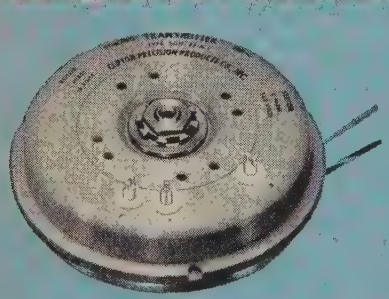

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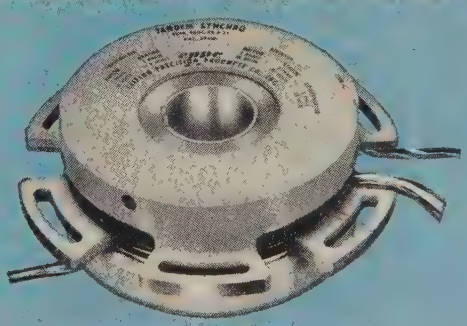

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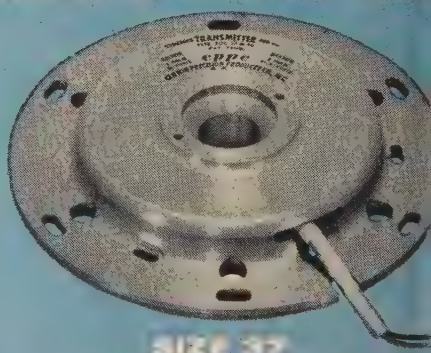

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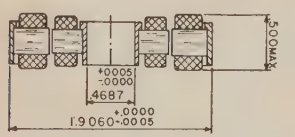

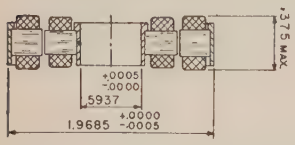

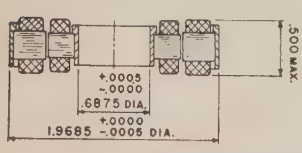

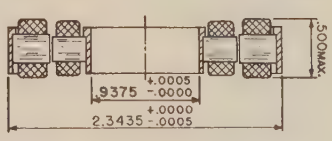

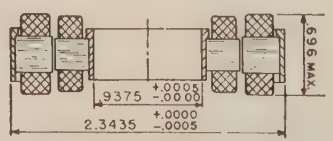

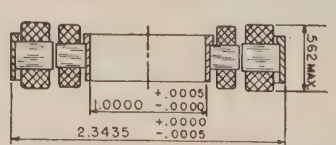

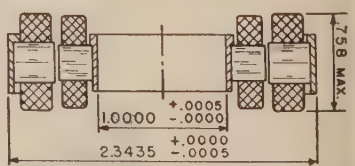

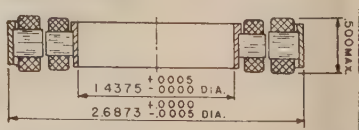

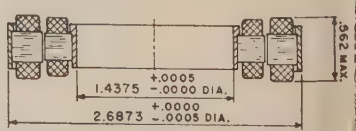

ENGINEERS—Pioneer with a leader in the field. Write David D. Brown, Director of Personnel, Dept. A3.

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No firm dates set now for molecular equipment

MOLECULAR ELECTRONICS apparently has not come along the development cycle as fast as ARDC and WADD once hoped. Only a year ago, USAF spokesmen were predicting operational molecular-design equipment by '63. Now no firm dates are mentioned. In a paper before the recent IRE conference in New York City, WADD's Col. William Heavner, former director of the Electronic Technology Lab and now director of the Electronic Recon Lab, talked in terms of "functional blocks" and admitted that there actually are two types of molecular electronics:

- the Westinghouse approach, which uses electric and magnetic phenomena in materials to produce the electronic effects.
- the Texas Instruments approach, which duplicates every component in a circuit, item for item; in a semiconductor block.

Formerly, the TI's approach was never mentioned in the same breath with Westinghouse's. In fact, according to previous ARDC statements, it was not included in the hazily defined "molecular electronics" family.

HEAVNER POINTED OUT that the *basic research* effort in molecular electronics was being made by Westinghouse. It's expected to result in a molecular VHF receiver by '62. He referred to TI's solid-state circuit program as more of a *"manufacturing methods"* approach. He said TI expects to put together a group of functional blocks to form complete units and to have field equipment ready for USAF by '65.

Transit I-B satellite was guided into successful orbit by a preprogramed system

SUCCESS OF TRANSIT I-B puts Navy in firmer position in the nation's space development program. The 265-lb spherical payload of the prototype navigation satellite was launched into orbit by a two-stage Thor-Epsilon vehicle. The second stage, after burning for 4.3 minutes, was shut down for 19 minutes. Then, by command of an internal programer, it was restarted and burned for 13 additional seconds.

A preprogramed system guided Transit I-B into orbit. There was also a radio-command backup, but it couldn't be used, because of the failure of a C-band beacon. A circular orbit was planned, but a timing error in shutting off the last stage resulted in an elliptical orbit with a 479-mile apogee and a 233-mile perigee.

Transit's payload carries five transmitters. Four are used to determine corrections for ionospheric refraction and the eccentricities in the shape of the earth. They are on 54, 162, 216, and 324 mc, respectively. The fifth transmitter is on 108 mc and is used for tracking and telemetry. BuWeps CLAIMS Transit will most likely be the world's first "operational" satellite. The Navy plans to put 4-6 satellites in different orbits circling the globe. Each will transmit on two frequencies and have distinguishing modulations. Ships, submarines, and land vehicles will be able to fix their position by determining the Doppler shift of received signals. With six satellites, a vehicle could get a position fix via Transit at least once every 90 minutes from any spot on the earth. An accuracy of at least ¼ mile is the goal.

Aircraft theoretically also could determine their position by Transit signals. However, because their problem is three-dimensional and the time constants are very short, they might require equipment that is so complex as to be economically unfeasible.

MADT power and frequency characteristics are extended by Philco

NEW TRANSISTOR fabrication process devised by Philco greatly extends the power and frequency characteristics of micro alloy-diffused-base transistors (MADTs). Called "etching by transmitted light" (ETL), it focuses high intensity light on one side of a semiconductor wafer while a jet of electro-chemical solution is directed at the other side. The light diffuses through the material and makes hole-electron pairs available at the other surface of the material. Speed and accuracy of the etching process are greatly increased

more on next page

Cover Story—"Grid Module" assembly technique, developed by General Electric's Heavy Military Electronics Dept. alows simple and cheap assembly of electronic parts in encapsulated modules.

and extremely flat surfaces that are 120 mils in diameter and larger become possible.

The new process, says Dr. C. G. Thornton, director of semiconductor R&D for Philco, brings out the inherent "unmatched frequency-power potential of the MADT design".

Transistors with dissipation ratings as high as 500 mw are now possible, says Thornton.

PHILCO HAS four commercially available transistors made by the ETL technique: 2N1204, 2N1494, 2N1495, and 2N1496. These, the company claims, have the highest switching rate among all available transistors: at a clock rate of 10 mc, they can switch currents as high as 400 ma.

Philco is developing a MADT-ETL device that can dissipate 15 W and switch one ampere at a five-megacycle clock rate.

K_a-BAND MAGNETRON, developed by Amperex Electronic operates at 35 kmc and produces an 0.02-usec pulse. The tube could be from the nucleus of future high resolution radars.

Beam-power tetrodes used in 150-W amplifier on Pioneer V

METAL-CERAMIC TETRODE just out of development at RCA's Electronic Tube Division may be responsible for man's longest radio communication. Two of the conductively cooled A-2629 beam-power tetrodes are used in a grounded-grid-cascaded 150-W amplifier in the payload of Pioneer V.

So far the amplifier has not been turned on. Signals are now being sent from Pioneer V via a five-watt transmitter. When the payload approaches the range limit of the five-watt transmitter (8,000,000-10,000,000 miles), the 150-W amplifier will be turned on by ground command.

Signals from the five-watt transmitter will be used to drive this amplifier, making it in effect a 150-W transmitter. The amplifier will be turned on around May 15.

INFRARED SEARCH-TRACK set for interceptors is being developed for WADD by ITT Labs. A miniature refrigerator, also developed by ITT, cools the detector in the unit to liquid-nitrogen temperatures. First models of the AN/AAR-21 search tracker have been delivered to WADD for ground and flight tests.

HANSCOM FIELD, Bedford, Mass., will be the focal point of future major USAF communications and electronic systems development. The recently formed AF Command and Control Development Division (AFCCDD), with headquarters at Hanscom, has been given the responsibility for developing USAF command and control systems for early warning and communications and intelligence. The Electronic Supporting Systems Project Offices (ESSPOs) now based at Wright-Patterson AFB, Ohio, and New York City also will move to Hanscom.

GALLIUM-ARSENIDE tunnel diodes are now in full production at Texas Instruments. The GaAs material, says TI, lets the component maker take full advantage of the performance predicted by tunnel-diode theory. Peak currents up to 10 ma ±2 per cent are guaranteed. Peak-to-valley ratios are 15. The diodes will operate in temperatures up to 150 deg C, says TI.

AUTOMATIC terrain avoidance system developed by Cornell Aeronautical Lab will be installed in a Martin B-57B for flight tests at WADD. The system is part of Project Autoflite, which started three years ago with feasibility studies.

CAL also developed a simulator for low altitude terrain avoidance flights. It consists of an F-84 cockpit, a terrain board, an analog computer, and data processing and recording circuits and can be adapted to various types of aircraft.

FAA plans many new electronic facilities in '61

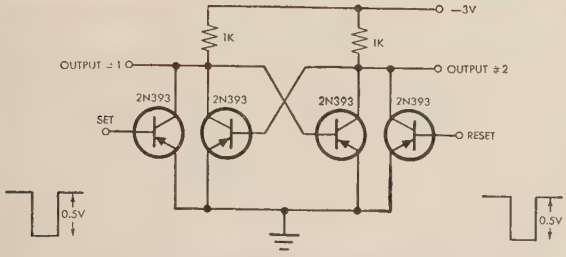
FAA WILL SPEND most of the $118 million it has programed for air navigation and traffic control for this fiscal year on electronics—especially on air traffic control radar. The new facilities it plans are:

- 20 airport traffic control towers;
- instrument landing systems at 15 airports;
- radar beacon systems on 24 long range radars;
- 18 terminal VORs;
- 20 Doppler VORs;
- 19 installations for direct air-ground communications;
- 500 installations of improved weather and traffic control teletypes (costing $5,612,800).

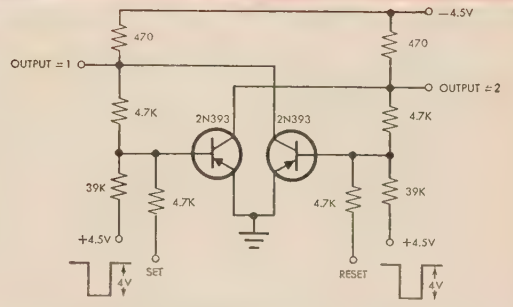
IN ADDITION, FAA will fit 16 long range radars with scan conversion equipment and equip 14

more on page 158

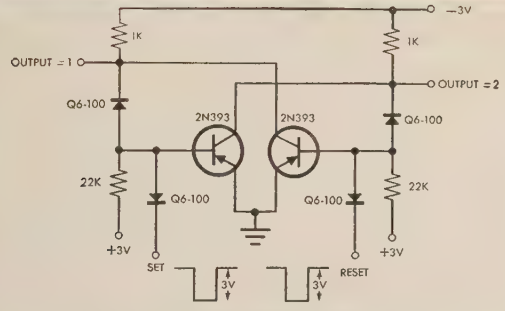
PHILCO MAT* TRANSISTORS are UNIVERSALLY APPLICABLE To All Logic Circuits Up To 5mc



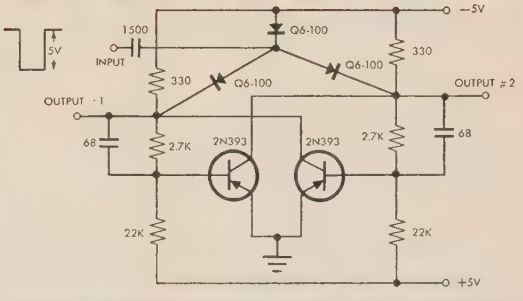
DIRECT COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=12 mμsec. t_f=15 mμsec.



RESISTOR COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=40 mμsec. t_f=110 mμsec.



DIODE COUPLED TRANSISTOR LOGIC FLIP-FLOP
TYPICAL SWITCHING TIMES: t_r=20 mμsec. t_f=60 mμsec.



RESISTOR CAPACITOR COUPLED TRANSISTOR LOGIC BINARY STAGE
TYPICAL SWITCHING TIMES: t_r=30 mμsec. t_f=44 mμsec.

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The Philco 2N393 Micro Alloy Transistor (MAT) has proved its complete reliability in millions of operating hours in every type of computer logic circuit up to 5 mc. It combines all the advantages of high frequency performance with low price. The 2N393 is easily designed into any logic circuit and offers the designer these important advantages:

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inspection aircraft with new instruments for flight-checking the accuracy of navaids.

In the future, FAA plans to set up a new international air traffic communications system at Cold Bay, Alaska, at a cost of $1.068 million, and to improve international aero communications at San Juan, P.R., at a cost of $1,207,660.

AIRBORNE RADAR must be installed in airline aircraft under a new FAA regulation:

- in passenger turboprops and turbojets by July 1;
- in Douglas DC-6s and DC-7s and Lockheed Constellation 1049s and 1649s by January 1961;
- in all other transport-category aircraft (except C-46s, Douglas DC-3s, Lockheed L-18s, helicopters, and aircraft used for cargo, testing, training, or ferry flights or operated solely in the Alaska or Hawaii areas, where thunderstorms are rare) by Jan. 1, '62.

Some 58 per cent of all U.S. scheduled airliners already carry weather radar. The ruling will mean sales of roughly 1000 new radars (counting spares) and will be a welcome boon to the three airline weather radar makers: Bendix, Collins, and RCA.

SIXTY PER CENT of nation's 66,000-odd general-aviation (non-airline civil) aircraft are now equipped with two way radio, according to a recent FAA survey.

Quesada doubts development of a system for aerial collision avoidance

COLLISION AVOIDANCE equipment has only a slim chance of ever being developed, in the opinion of Elwood Quesada, head of FAA. Quesada told a Senate subcommittee at the beginning of the year that ". . . great strides have been made [in developing an anti-collision device], but despite many years of previous research . . . there appeared no solution to the problem of installing a complete collision system aboard an airliner." He also said that such an installation would have to include an electronic computer, and this would be prohibitive. The FAA head told the subcommittee that new 3-D radars planned for busy airports would help prevent collisions within a 50-mile control zone.

WHAT QUESADA did not tell the committee, either because he was poorly advised or through inexcusable lack of familiarity with the anti-collision situation, is that our air collision prevention development efforts—the military's, FAA's and the scheduled airlines'—have been pitifully inadequate. A long time ago it seems our planners decided that the only way to solve the collision problem is to use good air traffic control practices in control zones (around busy airports) and to rely on the laws of probability outside these areas.

Many firms in the industry have been interested in doing research on the aerial collision prevention. But, despite a great amount of publicity on what the airlines and FAA intend to do in this area, there has been only a trickle of money for R&D. Interested companies complained that the airlines wanted free R&D—they would only pay for a device or system *after* it had been developed and proven. The airlines complained that most of the companies submitting proposals are prompted more by the need for a research contract rather than by practical ideas for solving the problem.

IT'S A SAFE BET that, should there be another aerial collision, both the airlines and FAA will reach down into their dusty files and start to review some of the proposals. They might even decide that putting a computer in an airliner is not too impractical an idea after all.

Far-infrared radiation changed into visible picture by new converter

PHOTOTHERMIONIC image converter announced by Westinghouse research labs changes far-infrared radiation into a visible picture on a cathode ray tube. Key component in the all-electronic system is a unique IR detector, or retina—a three-layer sandwich only a few millionths of an inch thick. The center layer of the sandwich is a thin support film of aluminum oxide that is about one millionth of an inch thick. The front of the film is coated with a layer of nickel and the back with cesium bismuth, a photo-emitting material. The latter's ability to release electrons under the stimulus of light varies with temperature, changing by two or three per cent for every degree of temperature change. The entire detector is cooled to around — 180 de F.

The front of the detector looks at the IR picture, and a spot of light is made to scan the photo-emitting layer. The variation of the electron emission intensity of this layer causes a corresponding modulation of the CRT screen.

more on page 160

LFE

is experienced . . . in Radar Surveillance Systems

The eye was man's first instrument of surveillance. Its most unique characteristic is the ability to distinguish moving objects.

LFE, a pioneer in motion detection by radar means, is prime contractor for a new Ground Control Approach System for tactical air traffic control. Now in production, it exemplifies the latest in lightweight, portable GCA equipment.

This is an illustration of LFE's interest in radar techniques with continued emphasis on motion detection. Such techniques are having an evolutionary influence on military and industrial systems.

Further details about LFE Radar Surveillance Systems may be had by writing the Vice President of Marketing. Ask for Technical Data Digest No. 6022.

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AIRBORNE NAVIGATION • RADAR and SURVEILLANCE • ELECTRONIC DATA PROCESSING • AUTOMATIC CONTROLS • GROUND SUPPORT

TOP GOVERNMENT and industry defense planners got together at the annual spring meeting of the Electronic Industries Association in Washington, D.C., to evaluate defense spending and discuss ideas for speeding up the production of new weapons systems. Generally they agreed we can expect high defense budgets to continue, but that the problems of planning weapons systems are growing and will require closer military-industry coordination. John M. Sprague, Deputy Assistant Secretary of Defense, pointed out that the electronics industry's share of defense money is forecast to increase over the next several years while the shares of other industries decline.

ACCORDING TO SPRAGUE, the rapidly changing spectrum of today's military planning complicates industry's participation in the planning of future weapon systems. "Military requirements, like the assessments of military threat, are not susceptible to precise determination," he declared. "Furthermore, the defense budget . . . must be developed within the framework of the entire Federal budget, the entire economic and fiscal policy, and, indeed, the entire national strategy."

Forecasts 20 per cent increase in electronics' share of defense budget

REAR ADM. L. O. COATES, Director of Development Planning, Office of CNO, foresees a 20 per cent jump in electronics' share of the defense budget during the next 20 years. He notes that the military electronics dollar increased from $560 million in '50 to $5.935 billion in '59 (or 14 per cent of all defense spending).

Coates gave these guidelines for keeping abreast of Navy's advanced planning: use Bureau contacts, make more visitis to Navy labs, keep track of what the military services testify to Congress.

•

OUR MOST ADVANCED spaceborne TV cameras are circling earth in what is reportedly the most elaborate electronics package yet orbited. The 270-lb Tiros I weather-recon satellite, designed to prove that you can get a global perspective on weather, had to be put into as nearly circular an orbit as possible at a predetermined altitude.

The excellent orbit that was achieved must be credited to Bell Labs' radio-inertial command guidance system—the same that is used to guide Titan. It has an eccentricity of 0.003; its dimensions are 387.7 nm at perigee and 407.2 nm at apogee.

Tiros was aimed for an injection inclination 48.29 deg relative to the equator. The actual measured inclination is 48.327 deg.

THE SATELLITE is spin-stabilized at a 12-rpm rate, so that its spin axis is kept within the plane of the orbit. It travels from west to east, circling the globe once every 89.3 minutes. RCA engineers predict its electronics will have a lifetime of about three months.

Tiros I carries two half-inch vidicon television camera systems—one for wide-angle views (with 400-line scanning) covering a 640,000-mile area; the other for high-resolution scanning covering (a 10,000 sq mile area).

Shaped like a drum and 42 in. diameter and 19 in. deep, Tiros I is covered on top and sides with over 9000 solar cells. Its electronics were put together under Signal Corps direction by RCA's Astro-Electronic Products Div., Princeton, N.J., for NASA. In addition to the payload, RCA was responsible for the ground checkout equipment.

Each of Tiros I's two cameras is served by two channels

TWO CHANNELS are used to serve each of Tiros I's cameras. There are two communications receivers, two precision electronic-clock mechanisms (for controlling sequencing), two magnetic video tape recorders, and two independent beacon systems operating on 108 and 108.03 mc, respectively. Two 330-oz, two-watt FM telemetry transmitters built by Radiation, Inc., transmit the video information on 235 mc. A single nickel-cadmium battery power supply is used to keep the solar cells charged.

COMPRESSED-BANDWIDTH technique holds the bandwidth down to 62.5 kc. Each tape recorder stores up to 32 single frames, exposed by the cameras during a single orbit. When the satellite comes within range of one of the two ground stations—Kaena Point, Hawaii, and Ft. Monmouth, N.J.—a command signal starts the tape readout to the transmitters for transmission to earth.

For picture-taking while within range of a ground station, the Tiros I cameras can be commanded to feed their information directly to the transmitters, bypassing the tape storage. Various programs of picture-taking for each orbit can be preset by command into the clock mechanism that triggers the cameras at the proper points.

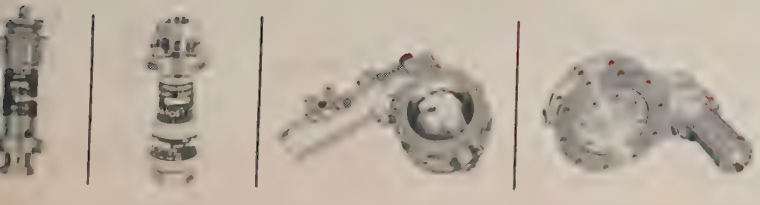
Write in No. 109 on Reader Service Card

Cryogenics

FOR THE FRINGES OF SPACE

When North American's X-15 carries man into the fringes of space, fourteen Stratos valves serving vital functions will be working away in its interior. These light, high-performance valves, typical of Stratos' broad cryogenics capabilities – both system and component – were designed and produced at its Western Branch.

Valves supplied for the X-15 include: butterfly valves for LOX and ammonia system; and 700 and 3900 psi relief valves.



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Pioneer V's UHF link

covers 50 million miles of space

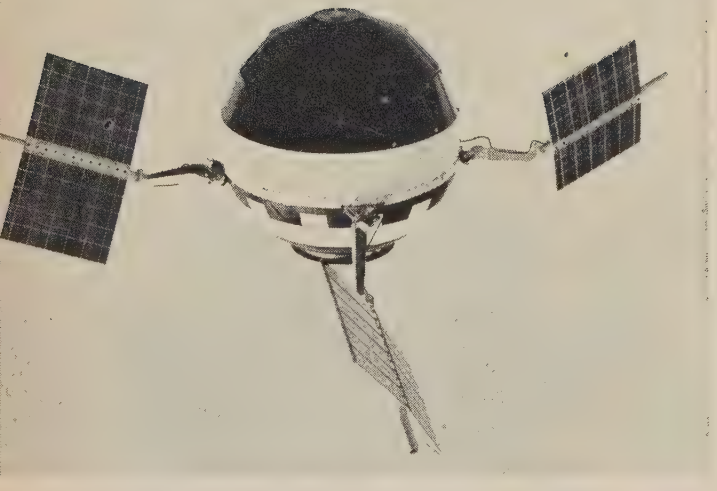
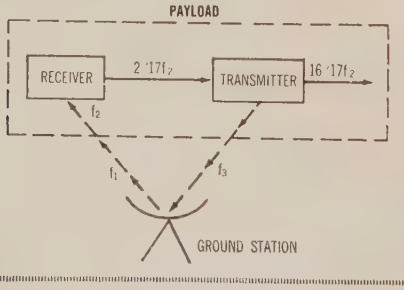


FIGURE 1: Payload of Pioneer V, now in orbit around the sun (above). Four solar paddles are extended (one cannot be seen in this shot). Each consists of a central aluminum alloy tube to which 12 modules of aluminum honeycomb are attached. The solar cells themselves are attached in series on each module. The black and white coatings on the sphere are carefully designed to give the proper absorptivity-emissivity ratio. The satellite's whip antenna sticks out at the top. Below: Ground-to-payload-to-ground communications sequence where $f_1 = 401$ mc, $f_2 = f_1 + \Delta f$, $f_3 = {}^{16}/_{17} f_1 + \Delta f = 378$ mc $+ 1{}^{16}/_{17}\Delta f$, Δf being the Doppler shift due to the payload's radial velocity.



The data gathered by Pioneer V, the solar system's newest planet, are being relayed to earth via a command telemetry system whose RF emissions span the greatest distance achieved in the history of communications.

by P. F. Glaser and E. R. Spangler
Associate Manager, Systems Engineering Dept., Experimental Space Projects, & Head, Briefings & Reports, Research Development Div., resp., Space Technology Laboratories, Inc.*

PIONEER V, as it whirls in its orbit around the sun, remains linked to the earth by electromagnetic threads —the longest ever spun by man. As you read this article, these threads will be some 10-15 million nm long. By July, they will have stretched to 50-60 million mn—about the maximum range of present communications facilities.

The space terminus of man's longest radio link is the 95-lb, two-foot-diameter spherical payload of Pioneer V. It contains a simple six-pound transmitter and a slightly more complex four-pound receiver, both working into a quarter-wave, omnidirectional whip antenna. Electric power comes from 28 nickel-cadmium cells charged by solar energy.

The transmitting and receiving equipment permits two-way communication between payload and earth on command from any of four ground stations (*Table I*). Actually there are two transmitters in the payload: a five-subminiature-tube five-watt unit effective out to 2,000,000 miles and a two-vacuum-tube 150-W unit. The five-watt transmitter serves as a driver for the 150-W amplifier; together the two make up the 150-W transmitter.

The Pioneer-V-to-earth communications sequence is (*Fig. 1*): A pulse-modulated 512-cps subcarrier phase-

* Space Technology Laboratories, Inc., Los Angeles 45, Calif.

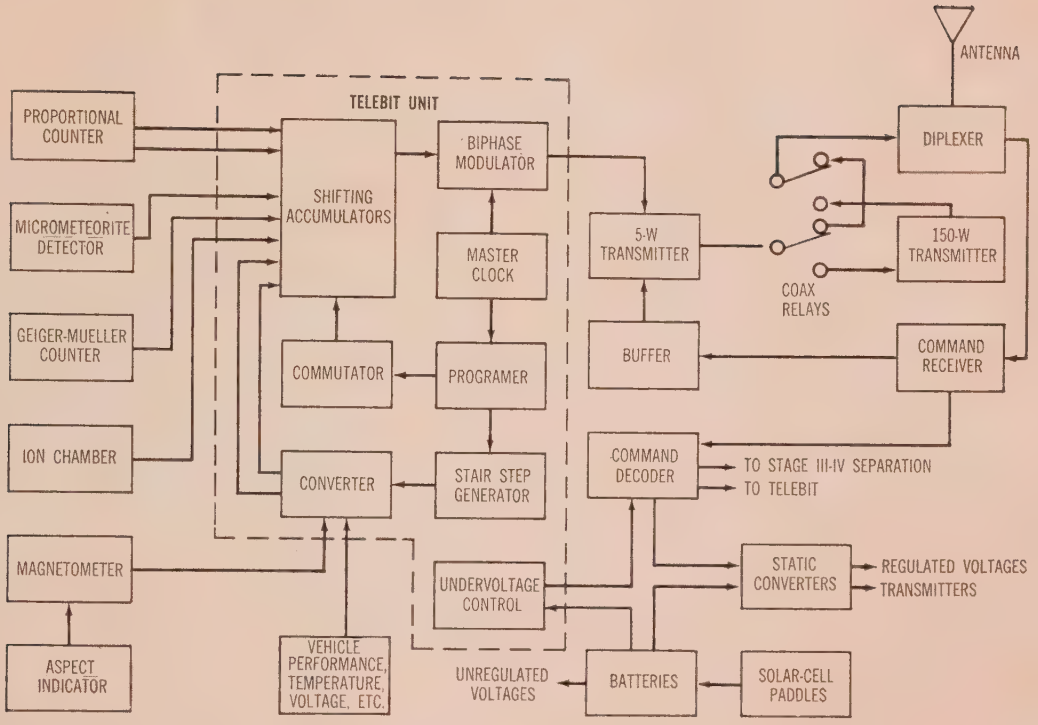


FIGURE 2: Electronics in the Pioneer V payload.

modulates a 401-mc carrier sent out from one of the ground stations. This signal (plus Doppler shift) is received by the payload receiver, which converts it to an output whose frequency is two-seventeenths of the input. This output is then fed to the transmitter, which increases it eightfold (to sixteen-seventeenths of the frequency of the receiver input). After phase modulation with a 1024-cps subcarrier, the output is transmitted back to the ground stations. The 1024-cps subcarrier contains the time-multiplexed code of the "Telebit" telemetry system. Biphase modulation is used to impress the telemetry output on the subcarrier. The efficiency of the 150-W transmitter is around 15 per cent.

Two methods increase the range

Two methods are used for increasing the communication range—one reduces time, the other reduces the information rate:

- The 150-W transmitter can be used instead of the five-watt unit. Because of its relatively high power drain, the larger transmitter can be used only sparingly, however.
- The information rate can be cut, which gives a lower transmission bandwidth and therefore a better S/N ratio for the communications link. The transmitters can be commanded to drop from a bit rate of 64 pps to eight pps and, for maximum range, to one pps.

Table II shows how the reception at the ground station from the payload varies. *Table I* shows roughly how the tracking situation changes as the payload recedes from earth.

The receiver operates continuously

The payload command receiver is a transistorized, double-conversion superheterodyne with a phase-lock loop. It produces a coherent output at two-seventeenth of the received frequency. The bandwidth is either 250 cps or 40 cps, depending on the ground command. The receiver operates continuously; as its bandwidth is considerably less than the frequency uncertainty of the ground-transmitted signal, it repeatedly sweeps in search of a carrier. At close range—3,000,000 miles or less—the sweep rate is 40 kc and the bandwidth 250 kc. At longer ranges, the sweep rate is cut to 18 kc and the bandwidth to 40 cps (to gain sensitivity at the expense of time).

The sweep period is 10 seconds for the wide band and three minutes for the narrow band. When the receiver acquires and locks on to a signal from the earth, the

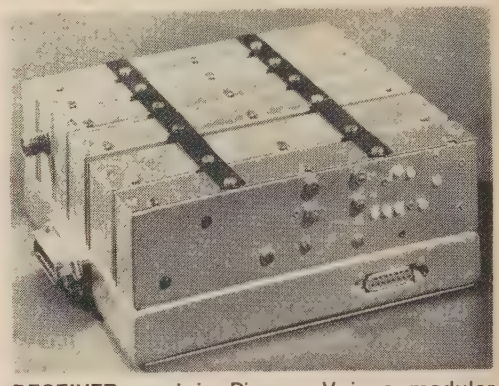
more on next page

Table I: Pioneer V Tracking

Days After Launch	Date	Range (nm)	Payload Transmitter Power (W)	Station	Information Rate (bits per second)	Remarks
5	March 16, '60	700,000	5	Cape Canaveral	1	Maximum range for Singapore & Cape Canaveral
				Singapore	1	
				Hawaii	8	
				Manchester	64	
14	March 25, '60	2,000,000	5	Hawaii	1	Maximum range for 5-W transmission to Hawaii
				Manchester	8	
72	May 22, '60	15,000,000	150	Hawaii	1	Maximum range for Hawaii
				Manchester	8	
142	July 31, '60	60,000,000	150	Manchester	1	Maximum range

Table II: UHF Ground Antenna Gain

Manchester, England (250-ft parabola)	45.6 db
Hawaii (60-ft parabola)	33.7 db
Singapore & Cape Canaveral, Fla. (five-helix Rantec arrays)	25.0 db



RECEIVER used in Pioneer V is a modular design weighing four pounds. A double-conversion superheterodyne, it uses a phase-lock loop.

sweeping stops and the receiver can then accept any of eight possible commands;

- Transmitters off.
- Five-Watt Transmitter on at 64 pps.
- Five-Watt Transmitter on at Eight pps.
- Five-Watt transmitter on at One pps.
- Separate Stages III and IV (of the launch vehicle).
- Receiver Narrow Band.
- 150-W Transmitter Plates on.
- 150-W Transmitter Filament on.

Signals from the earth to the payload are transmitted by a high-powered 401-mc carrier phase-modulated with a 512-cps subcarrier. Phase modulation of the subcarrier with a coded train of 13 pulses provides the required information to the payload command decoder. The receiver weighs four pounds, takes up 1300 cu in., and draws 1.5 W at 16 V dc input.

Range rate is measured to one fps

The range rate is measured on the ground to accuracies of one fps by extracting the two-way Doppler frequency shift between the transmitted and received signal (after correction for the frequency offset caused by the vehicle transponder). Range is measured by frequency-modulating the ground transmitter with low frequency sinusoids. A modulating frequency of 16 cps provides a range resolution of better than 100 miles if smoothing is adequate.

A second modulating frequency of two cps is used to resolve the phase ambiguities in the 16-cps signal; a third modulation frequency of 0.25 cps resolves the phase ambiguities in the two-cps signal. Further ambiguities are resolved by measuring the time delay between the start of modulation on the ground and the start of modulation in the return signal.

Tracking in angle is done by nodding the ground antenna alternately in elevation and azimuth as it aims at the payload. Angular accuracies of about 0.2 deg are possible with the four-station ground network. Trajectory smoothing by the ground network can provide velocity and angular measurements within 0.01 deg and 0.1 fps after a few days of tracking.

Analog and digital inputs accepted

Pioneer V's Telebit digital telemetry system, developed by STL, accepts both analog and digital inputs from the various experiment and payload performance transducers (*Fig. 2*). The converted information appears as a binary-coded 1024-cps subcarrier, which then phase-modulates the transmitted carrier. Seven separate "words" are sent to the ground each time the payload transmits: (1) triples proportional counter; (2) singles proportional counter; (3) micrometeorite two-level counts; (4) Geiger-Mueller counter; (5) ionization chamber; (6) magnetometer; (7) subcommutator measurements. In the last word, eight subcommutated payload performance measurements are transmitted: (1) forward-paddle temperature; (2) aft-paddle temperature; (3) transmitter heat sink temperature; (4) battery temperature; (5) internal ambient temperature; (6) converter heat sink temperature; (7) battery voltage; (8) receiver phase error.

The binary output of the Telebit system has a synchronous rate and consists of repeating sets of frames

of words. On the Pioneer V, eight words are used per frame. One word in each frame is used for frame synchronization and read out as all zeros; the other words are coded with the digital representation of the input information. Each word contains 12 pulses. The first two pulses (for information words) always have the same code (zero, one) and define the start of a word, providing a word synch. The other 10 pulses may take on any combination of binary values to represent any number from zero to 1024.

Shifting accumulator for each word

A shifting accumulator, which is a 12-bit combined binary counter and shift register, is provided for each word. Pulses from a digital measurement are applied directly to the counting input of a shifting accumulator; an analog input is applied to an analog-digital converter, whose output is then applied to a shifting accumulator. An electronic commutator running synchronously at the word rate gates 12 shift pulses to each shifting accumulator during one word interval in each frame.

Because of these shift pulses, the information in the shifting accumulator is delivered to the biphase modulator while the output of the digital shifting accumulators is returned to the input—so, after every 12 shift pulses, the state of the shifting accumulators is exactly the same. The outputs of all the shifting accumulators are connected, but as only one is shifting at any time, no interference results.

Information is converted from analog to digital with a digital ramp and a voltage comparison circuit. Essentially it is a matter of counting the number of steps in the ramp below the level of the analog input. The counting is done in a shifting accumulator, just as for the digital experiments.

The biphase modulator accepts the pulses emerging sequentially from the shifting accumulators and produces a subcarrier whose phase shifts by 180 deg each time a zero is to be transmitted. This biphase-modulated subcarrier is then fed to the transmitter, where it phase-modulates the carrier.

Solar sails charge the batteries

The pulses that cause the electronic commutator to step and the shift registers to shift come from the programer, and the programer in turn receives its excitation from a master clock. When energized by the proper signals from the command decoder, the programer changes the pulse rate of the Telebit system to 64, 8 or one pps.

If Pioneer V's solar cells had been placed directly on the surface of the payload, two problems would have arisen: (1) Not enough surface area was conveniently available for adequate solar-energy interception. (2) The temperature balance of the payload would have had to be too low for the internal instrumentation. It was early decided, therefore, to put the solar cells on paddles extending essentially radially from the payload. The paddles fold within the nose fairing during launch; at second-stage burnout, after the fairing has been jettisoned, they spring out and latch into place. A total of 4800 boron-diffused silicon solar cells is carried on the satellite. Because of attitude and spin, however, only about 1000 cells are receiving solar energy at any given time.

The payload storage battery consists of two packs of 14 nickel-cadmium cells each. Part of the power developed in the solar cells is immediately consumed in experiments and in the receiver, and the charging rate of the battery is reduced by this amount. The five-watt transmitter, which draws a large portion of its power from the batteries, can operate roughly 15 per cent of the time; the 150-W transmitter can operate roughly two per cent of the time. The nominal power available from the solar cell conversion system is about 15-W when the payload is near the earth and about 24-W at perihelion.

The batteries deliver 16-19 V. Since this voltage is inadequate for all of the electronics, a series of static converters is used to provide a variety of voltage levels. An undervoltage control automatically removes the transmitter load from the batteries when the battery discharge threatens to disable the receiver and keep the payload from being commanded from the ground. In addition this control insures the conservation of battery life by preventing large battery discharges.

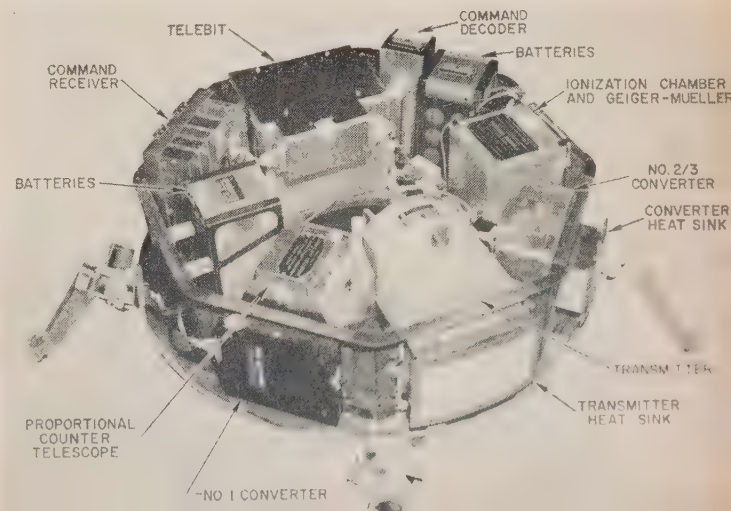
Temperature is kept to 35-80 deg F

The temperature of the payload is kept within the desired range of 35-80 deg F by heat sinks and by black and white coatings on the outside of the payload sphere. The heat generated by the transmitters and converters is absorbed by lithium heat sinks at the sites of this equipment. These sinks then radiate the heat into space. The operation of the transmitters and converters therefore does not significantly incease the general temperature of the payload.

The payload coating is carefully prepared so that the payload shell's ratio of absorptivity to emissivity of solar energy varies with attitude as calculated to keep the temperature within the proper range while the payload moves toward the sun. Because the attitude of the vehicle with respect to the sun does not vary steadily with time of flight, this technique cannot yield a constant payload temperature, but the deviations from the steady variation are not so large that the temperature couldn't be kept within the acceptable range.

Glass plates of 0.003 in. thickness on the solar cells, keep the temperature of the cells within the operating range. On the underside of the plates, interference filters are vacuum-deposited. The paddles are also coated between shingles of cells to keep temperature down. At perihelion, the cells operate in the range of 60-100 deg F.—End

ELECTRONIC PACKAGES are arranged about the octagonal interior of Pioneer V's payload.



Hidden design factors for thermoelectric coolers

In the design of thermoelectric coolers, we're ready now to start applying our lab know-how to practical, operational devices. However, we won't succeed if, in the general rush to capitalize on our research gains, we fail to allow for the subtle but critical parameters of the new thermoelectric medium.

by J. C. Carroll, Staff Engineer
New Products Engineering Dept.,
Westinghouse Electric Corp.*

ONLY SOME 30 YEARS AGO, thermoelectric refrigeration was considered to be flatly impractical. This pessimistic attitude was based on the assumption that metals make the best material for thermoelectric elements. Then, in 1929, a Russian, A. F. Ioffe, showed that it is possible and profitable to use semiconductor thermo-elements for generating, refrigerating, and heating devices. He even predicted that such devices would one day compete economically with the modern compressor-type refrigerator.

In recent years, a number of thermoelectric cooling devices—mostly experimental—have been built. Thanks to the advances we have made in the fabrication of semiconductor materials with suitable thermoelectric characteristics, thermoelectrics now can be applied in practical cooling devices.

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However, we must not lose sight of the fact that not all the designer's troubles are over yet. There are certain problems and intricacies in designing in thermoelectrics that must be recognized from the start if you want to stay out of serious trouble. Working in this new medium, you find, for instance that, in addition to the cooling derived from the Peltier effect, there are two adverse effects that reduce the net cooling rate:

- Joulean heat loss, due to the electric current flowing in the thermoelectric material,
- heat loss by conduction from the hot to the cold junction through the thermoelectric material.

You want your thermoelectric material to have both a low electric resistivity (ρ) to reduce the Joulean heating loss and a low thermal conductivity (k) to reduce the thermal conduction loss. A large Seebeck coefficient (S) is also required, since it is proportional to the gross cooling effect. You can combine these material constants to form a figure of merit (Z), defined as:

$$Z = S^2/\rho k, \tag{1}$$

and has the dimensions of the reciprocal of the temperature squared.

To increase Z, you have to reduce electric resistivity and thermal conductivity and increase the Seebeck coefficient. (S is the most important of the three parameters, since Z is a function of its second power. These physical parameters are not absolute but rather a function of the temperature. *Figure 1* shows the relationships of Z to the cold and hot junction temperatures for a typical bismuth-telluride couple.

The gross heat-pumping rate of a Peltier junction is given by:

$$Q_T = \pi I \text{ watts}, \tag{2}$$

where I is the electric current (in amperes) and π is

the Peltier coefficient. The Joulean heat loss is given by:

(3) $$Q_J = \tfrac{1}{2} I^2 R,$$

where R is the sum of the resistances of the two thermoelements. Mathematically it can be shown that only half of the Joulean heat is conducted to the cold junction. The heat loss due to thermal conduction is:

(4) $$Q_h = (kA/l)(T_h - T_c),$$

where A is the area of the pellet (in cm²); l, length (in centimeters); T_h, the temperature of the hot junction (in degrees K); and k, the sum of the thermal conductivities of the two thermoelectric pellets.

The net heat-pumping rate of the cold junction of a Peltier couple then is:

(5) $$Q_c = \pi I - \tfrac{1}{2} I^2 R - (kA/l)(T_h - T_c)$$

and the net heat-pumping rate of the hot junction is:

(6) $$Q_H = \pi I + \tfrac{1}{2} I^2 R - (kA/l)(T_h - T_c).$$

Interesting variation of cooling

The variation of the net cooling rate of a Peltier couple with current is interesting. Let us assume that the two junctions of a couple are maintained at two fixed temperatures. If no current flows, there will be a flow of heat to the cold plate that we may define as the thermal conduction loss (Q_h). As the current is increased, the Peltier effect (Q_T) overtakes Q_h, and there is heat absorption (Q_c) at the cold junction. Since the rate of the Joulean heat (Q_J) increases as the square of the current, it increases faster than the Peltier effect and will be greater in magnitude at some finite current. There is therefore a maximum value of the net cooling rate per couple at given hot- and cold-junction temperature (*Fig. 2*).

To find the magnitude of the current required for operation, the partial derivative of *Equation 5* is taken with respect to the current:

(7) $$\partial Q/\partial I = \pi - IR.$$

We can say that the required current is:

(8) $$I_i = \pi/R.$$

We can now solve for the maximum cooling rate per couple:

(9) $$Q_c\,max = \tfrac{1}{2}\pi^2/R = \tfrac{1}{2} Q_H.$$

Efficiency of cooling is defined

The efficiency of a cooling device is defined as the ratio of the cooling rate to the input power, or the coefficient of performance (*COP*). For thermoelectric devices, it can be written as:

(10) $$COP = Q_c/I^2R + 2\pi(T_h - T_c/T_c)I.$$

Obviously, *COP* as a function of current also has a maximum value. Unfortunately, though, this value does not occur at the same current as the maximum heat extraction rate. To find the current at maximum *COP* we take the partial derivative of *COP* with respect to the current:

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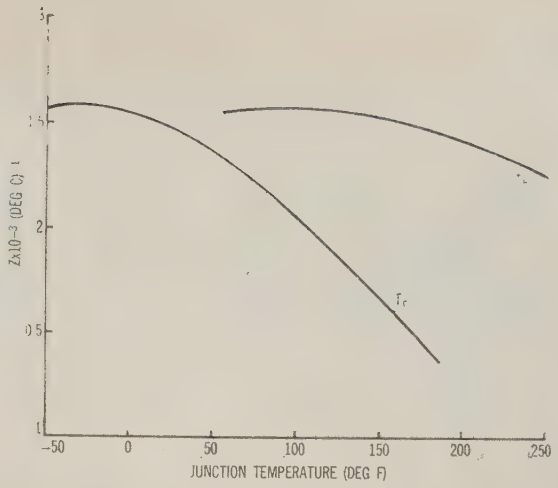


FIGURE 1: Figure of merit vs hot- and cold-junction temperatures at maximum temperature differential and Q = 0.

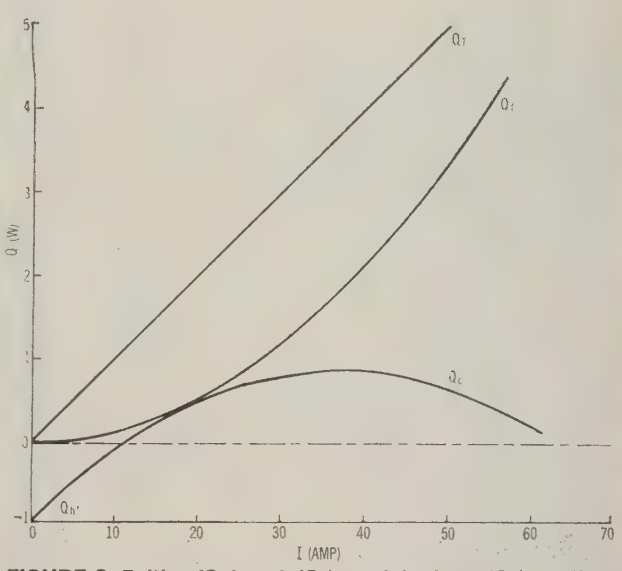


FIGURE 2: Peltier (Q_T), net (Q_c), and Joulean (Q_J) cooling and thermal-conduction loss (Q_h) vs current for $T_c = 35$ deg F and $T_h = 115$ deg F.

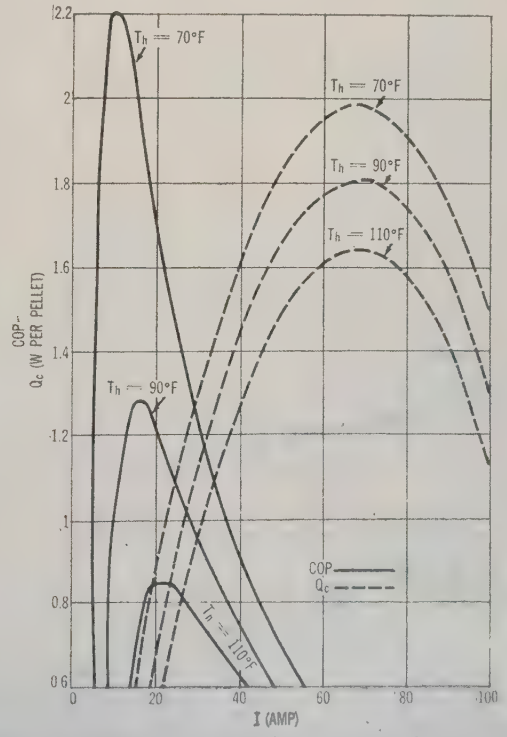


FIGURE 3: Coefficient of performance and net cooling rate of a Peltier couple at a cold-junction temperature of

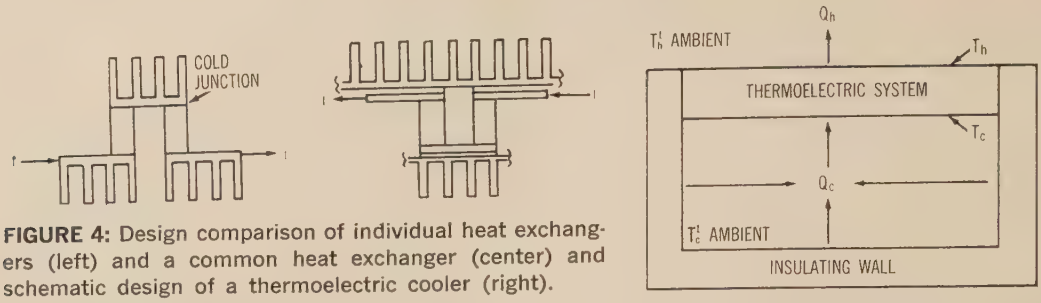


FIGURE 4: Design comparison of individual heat exchangers (left) and a common heat exchanger (center) and schematic design of a thermoelectric cooler (right).

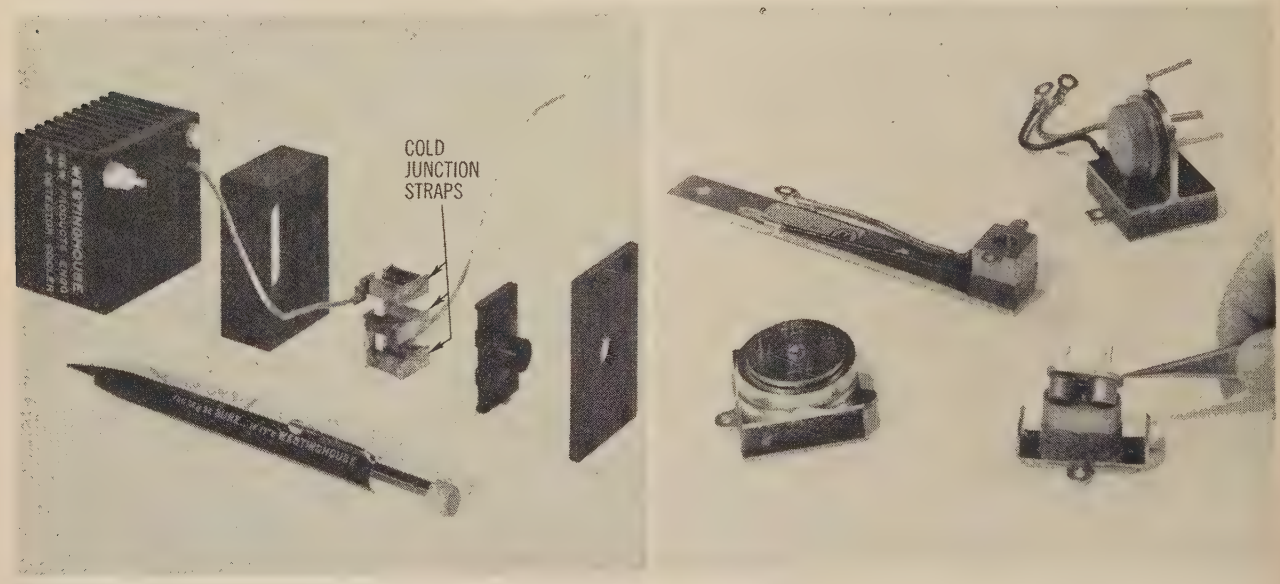


FIGURE 5: Exploded view (left) of a thermoelectric infrared cooler. Right: Commercially available thermoelectric cooler modules. The module in the right foreground is used to chamber-cool two transistors.

(11) $I_g = [\pi(T_h - T_c)]/[RT_c(\sqrt{1 + ZT_M} - 1)]$,
where T_M equals $T_h + T_c/2$.

To find the cooling rate, we construct:

(12) $Q_{cl} = (T_h - T_c)$

$$\left[\frac{\pi^2}{RT_c\sqrt{1 + ZT_M} - 1}\left(1 - \frac{T_h - T_c}{T_c\sqrt{1 + ZT_M} - 1}\right)\right] - Qh).$$

Figure 3 plots typical cooling-rate and *COP* curves for a Peltier pellet for various hot-junction temperatures as a function of current. The design point for any given cooling device depends on the device's application. Operation at the maximum heat rate minimizes thermoelectric size and cost, while operation at maximum *COP* minimizes the operating cost.

Heat transfer is still a problem

In applying thermoelectrics to a cooling system, you must coordinate the design of the thermoelectric section with that of the heat transfer members. Since the thermo-elements merely serve as heat pumps, you still face the problem of making it easy for heat to enter at the cold junction and of removing the heat at the hot junction. A simple solution is to make the individual heat exchangers integral with each hot and cold junction *(Fig. 4)*.

Usually, the electric excitation for a Peltier couple occurs at a low voltage and a high input current. In most practical devices, the thermoelectric assembly requires two or more couples that are electrically connected in series but whose hot and cold junctions are grouped in the same plane. So you have the obvious disadvantage of several adjacent heat exchangers that are at different electric potentials.

Common heat exchanger can be used

An alternate design for a multi-couple device would be to use a common heat exchanger for all the hot or all the cold junctions (*Fig. 4*). This method gives you the advantage of an electrically insulated structure, but the single heat exchanger is less efficient than a group of heat exchangers. To minimize the thermal impedance between the heat exchanger and the junction, you must remove all air films.

Figure 4 also shows a typical thermoelectric cooling

technique. Heat leaks through the insulation of the walls into the cooling chamber. The cold surface—at temperature T_c—picks up this heat by radiation and convection. The heat and the pump power are pumped to the ambient at temperature T_h^1. Note that the hot side of the thermoelectric system is at temperature T_h, which exceeds T_h^1. The design of your heat exchanger determines this temperature differential. For most applications, it is best to design for as small a differential as size, weight, and the mechanical properties of the cooling device will allow.

Equations give operating parameters

You can find the necessary number of thermoelements of a given size as well as the operating current for your cooling applications from *Equation 9* or *12*, depending on the operating point you want. *Equations 7 & 9* you can use to find the current you need for operation at maximum heat-pumping rate and maximum *COP*, respectively. By taking the product of current, number of couples, and resistance per couple added to the Thomson effect (which is the product of differential temperature, thermoelectric power, and number of couples), you find your excitation voltage.

Figures 6 & 7 help you to find the cooling rate per pellet. *Figure 6* plots curves for the heat pumping rate at maximum *COP* as a function of the temperature differential between the hot and cold junctions for thermoelements of various figures of merit. Since the input power (P_{in}) per pellet is also shown, you can define *COP* by taking the ratio of Q to P_{in} for a given Z and ΔT. *Figure 7* plots similar curves for operation at maximum heat-pumping rate.

An example of the most elementary application for a thermoelectric cooling device is the infrared detector cooler of *Figure 5*. This is a three-couple device with a heat-extraction rate of 0.3 W. It keeps the temperature of a missile-borne IR detector at 10 deg C in 30 deg C ambient. The copper straps on the right side of the pellets are actually cold-junction straps that butt against the cold plate.

Standard "thermoelectric modules"

Because of their compactness, thermoelectric devices can be used for many spot-cooling applications in airborne electronics to meet problems of widely varying operating conditions and installation in remote areas. Recently, Westinghouse came out with a line of "thermoelectric modules" in several standardized forms (*Fig. 5*). These modules are designed in a variety of shapes and sizes for simple mounting in various positions. For instance, you could mount a number of them on the inner sides of a box shape to form a compact space cooler for electronic equipment. The modules are designed to cool either one or several electronic devices.

Modular construction gives you much more flexibility of application. In many cases, it means that the electronics need not be redesigned to accommodate thermoelectric spot-coolers.—End

REFERENCES—A. F. Ioffe, "Semiconductor and Thermoelements and Thermoelectric Cooling"; Infosearch, London, '57. R. L. Eichborn, "Thermoelectric Refrigeration"; *Refrig. Engrg.*, 66/6 ('58). S. V. Galginaitis, "Physical Properties of Thermoelectric Materials"; *Refrig. Engrg.*, 66/7 ('58). R. S. Lackey & J. D. Somers, "Application of Thermoelectric Cooling and Heating"; *Refrig. Engrg.*, 66/12 ('58).

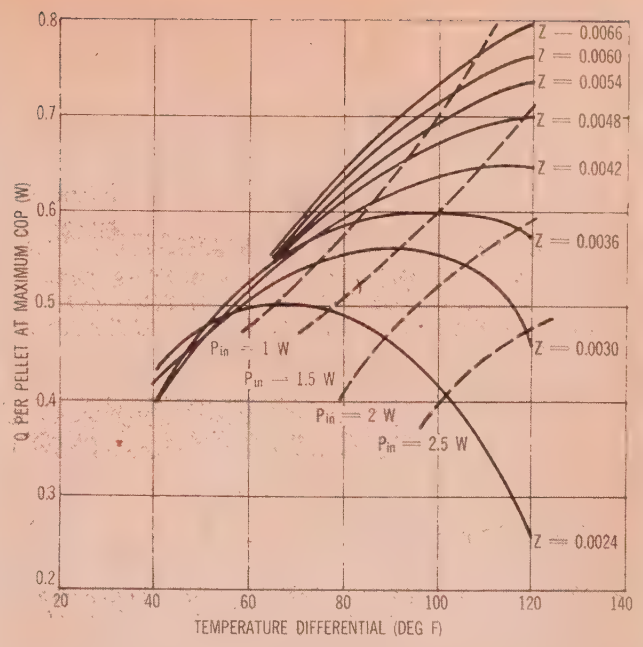


FIGURE 6: Heat-pumping rate per pellet at maximum COP vs temperature differential for various figures of merit. The dashed curves are for various input powers per pellet at $T_c = 40$ deg F.

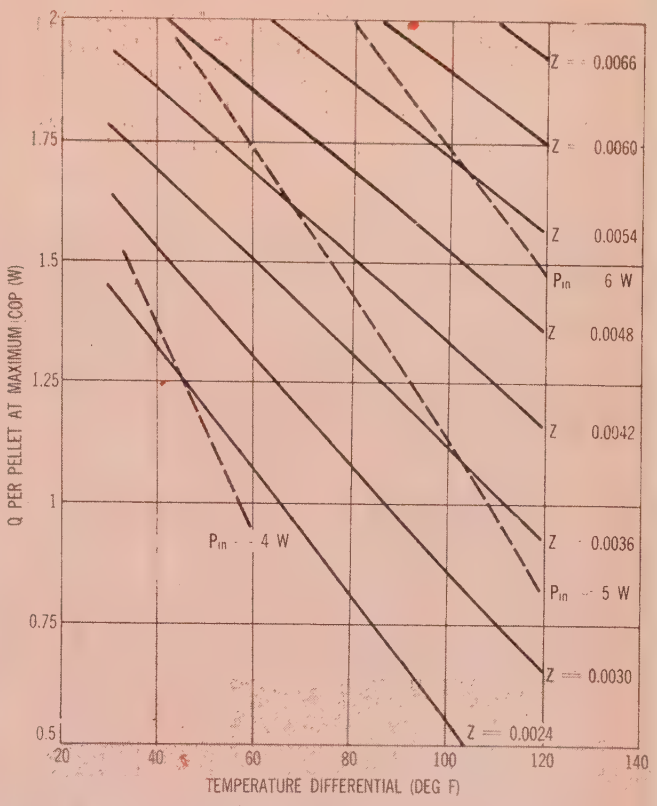


FIGURE 7: Maximum heat-pumping rate per couple vs temperature differential for various figures of merit for a cold-junction temperature of 40 deg F and a pellet shape whose length-area ratio is one cm^{-1}. The dashed curves are for various input powers per pellet.

Just how transparent is your radome?

Radar performance characteristics, as stated by the radar manufacturer, never include the effect of the radome. Yet when a radar has to operate from inside a radome, the true performance is that of the entire system: radar and radome.

by Dalton A. Bell, Assistant Research Group Engineer, Convair-San Diego*

RADOMES ARE DESIGNED to be "radar-transparent" — only they never quite are. All have some deteriorating effect on the radar antenna pattern, since they reflect, refract, diffract, and absorb some of the radiated energy.

Airborne weather radars typically use parabolic reflectors mounted inside a radome on the nose of the aircraft. The secondary pattern of these radars is a pencil beam of C- or X-band energy. This beam is scanned over a sector in front of the aircraft to search out turbulent weather.

The principal undesired effects of a radome in an airborne weather radar system are losses in maximum

* Convair Div., General Dynamics Corp., 3165 Pacific Highway, San Diego 12, Calif.

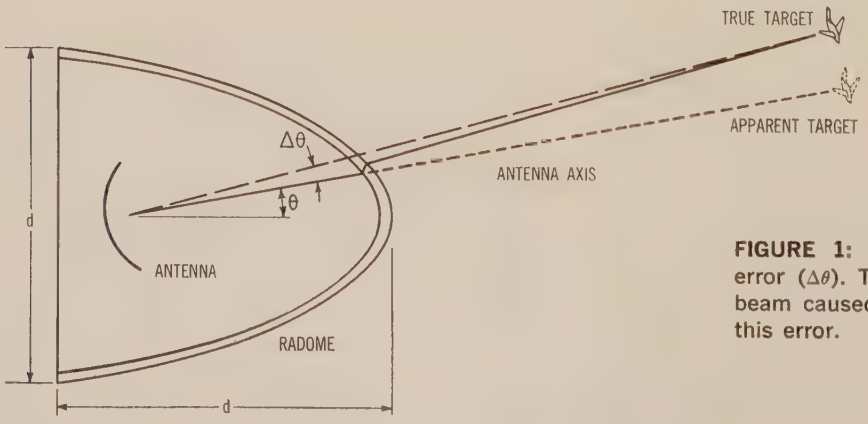


FIGURE 1: Geometry of the radome error ($\Delta\theta$). The refraction of the radar beam caused by the radome produces this error.

radar range and angular resolution. Both can be analyzed in terms of disturbances that the radome causes in the antenna pattern.

The range losses stem from power transmission losses, which generally occur when you propagate through a radome. The transmission losses are due to absorption, reflection, or diffraction. For radomes made of materials with a loss tangent of less than 0.015, the energy lost to absorption by the radome walls and eventual conversion to heat is negligible. Typical current materials, that meet the loss tangent requirements are fiberglass cloth and epoxy or polyester resins.

The principal losses, however, are caused by reflection at the radome interfaces and by diffraction effects. Both redistribute the energy within the radiated beam; even though this energy propagates through the radome, it is usually counted as a loss since the generally accepted testing procedure measures only the power transmitted in the peak direction of the radiated beam.

Transmission loss is figured by comparing the power transmitted in the peak direction from the uncovered antenna with that transmitted in the same direction from the antenna covered by the radome. Natually, if more power is concentrated in the direction of the peak of the beam, because of diffraction a gain rather than a loss will result. More often the reverse is true, and the diffracted energy broadens the main lobe and increases the strength of the side lobes. In the latter case, the transmitted power in the peak direction is lower than the power measured in that direction from the uncovered antenna, and there is a transmission loss.

This loss can be interpreted either as a loss in the power transmitted by the antenna or a reduction in antenna gain. In any event, it always means a lower maximum range.

One radome spec. may state that the gain of the antenna-radome combination must be so and so many decibels, while another might say the same thing by separately calling out the antenna gain and the radome loss (in decibels or percentage). Here we will analyze radome losses in terms of the effect on the antenna's radiated power.

The parameters or our problem are shown by the radar range equation:

$$R_{max} = [P_t \lambda^2 G^2 \sigma / (4\pi)^3 \overline{NF}\, kT\beta]^{\frac{1}{4}},$$

where P_t is power transmitted by the antenna; λ, wavelength; G, antenna gain; σ, radar cross-sectional area; NF, receiver noise figure; k, Boltzmann's constant (1.38×10^{-23} joules/deg); T, absolute temperature; and β, bandwidth. We see that the maximum range varies as the fourth root of the power transmitted by the antenna. The radiated energy traverses the radome wall twice as it goes to and returns from the target. Each time it is attenuated, so that only part of the incident energy is transmitted. The fractional part that is transmitted (t) is known as "one-way power transmission coefficient."*

more on next page

* The symbol "t^2" is generally used to represent the one-way power transmission coefficient, since calcuations of transmission through dielectrics are based on amplitude, while the power is proportional to the square of the amplitude. For the sake of simplicity, however, we will here use "t".

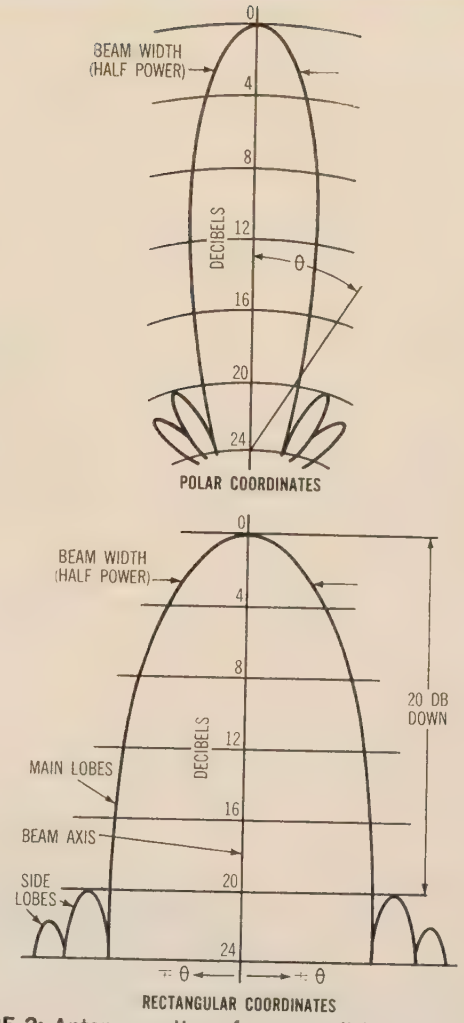


FIGURE 2: Antenna pattern for a pencil beam as used in airborne weather radars.

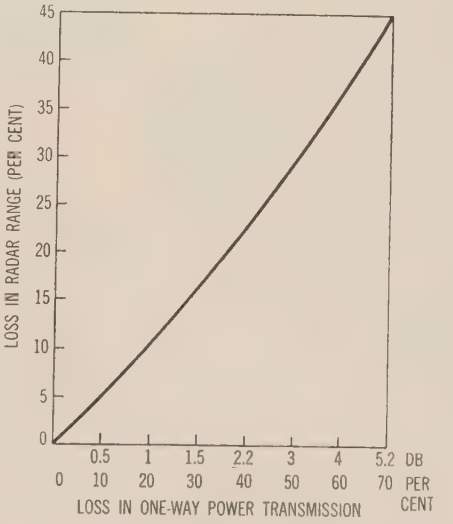


FIGURE 3: Reduction in radar range as a function of radome loss.

The total fractional loss for a radome of the type used on active weather radars is t^2, since energy twice passes through the radome wall. The ratio of the radar ranges with the radome (R_{max}) and without it (R'_{max}) is:

$$R'_{max}/R_{max} = (t^2 P_t/P_t)^{\frac{1}{4}} = t^{\frac{1}{2}}.$$

If t is 70 per cent (or seven-tenths of the energy incident on the radome is transmitted), then:

$$R'_{max} \approx 0.84 R_{max}$$

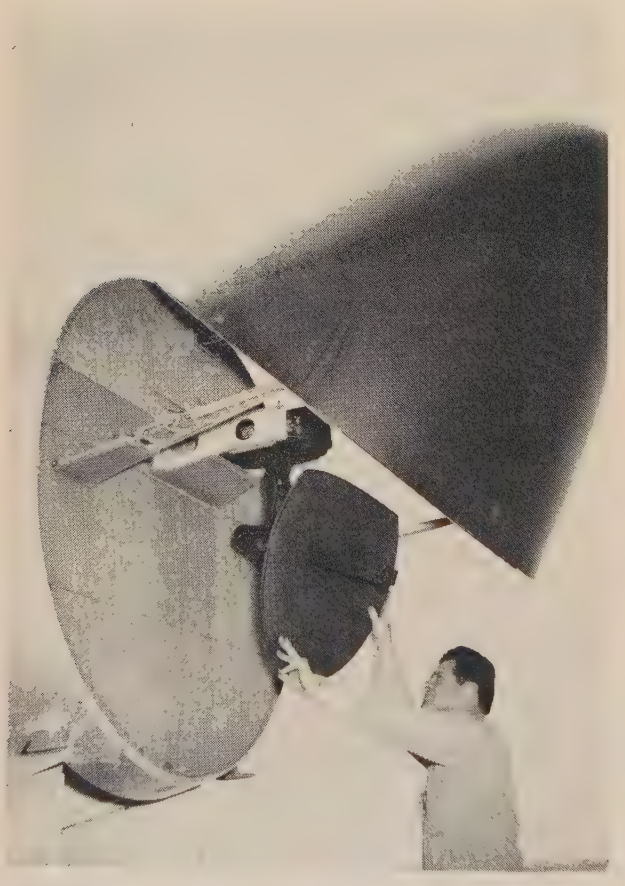
A simple formula for approximating the effect on the radar range states that the percentage loss in range equals half the one-way power loss in per cent, as is shown by:

$$\textit{percentage loss in range} = [(R_{max} - R'_{max})/R_{max}]\,100$$
$$= [1 - (R'_{max}/R_{max})]\,100 = (1 - t^{\frac{1}{2}})\,100 = [(1 - t)/2]\,100,$$
$$t \approx 1.$$

The term $1 - t$ represents the power loss in one-way transmission through the radome.

As an example, assume the one-way power transmission loss is one decibel—70 per cent of the power is transmitted and 21 per cent is lost. The reduction in range is half of 21 per cent, or 10.5 per cent (*Fig. 3*).

If the maximum operating range of the weather radar in this case of 150 miles, then its range with the radome on will be 150—0.105×150, or about 134 miles. At a speed of 600 mph, this allows slightly more than 13 minutes for the selection of an alternate route, if an atmospheric disturbance is detected at the maximum range.



RADOME swings upward on the nose of the Convair 880 jet transport to make the weather radar antenna accessible. The radar is a C-band set made by Collins Radio. Its maximum range and angular resolution can be reduced by radome effects, which can be analyzed in terms of disturbances in the antenna pattern.

Radar resolution is defined as the ability of the radar to distinguish two reflecting objects that lie close together. As viewed from the antenna, the objects may differ in range or angular separation. Range resolution is primarily a function of the transmitted pulse length and is not affected by the radome. The angular resolution varies inversely with bandwidth. Objects equally distant from the antenna can be resolved if they are equal to or greater than one beamwidth.

The radome may broaden or narrow the beam. Decreasing the beamwidth obviously enhances the resolution, while beam broadening reduces it. A transmission loss usually is accompanied by beam broadening, since the radiated power diffuses over a large area. Beam broadening up to 10 per cent of the free-space half-power beamwidth is acceptable. Actually the difference in resolution from a given pencil beam and another 10 per cent wider can't be noticed on a five-inch PPI display even by a trained operator.

As the antenna scans, the beam moves through the space surrounding the aircraft. The PPI is synchronized with the antenna and recognizes only that the antenna is pointing at an angle (θ) relative to a reference direction. When the beam passes through the radome, it is refracted and the beam axis is bent. The signal reflected by the target returns to the antenna via this bent axis, so that the true point direction to the target is $\theta + \Delta\theta$ and not θ.

On the PPI, the target is presented as at angle θ from the reference, so there is an angular error of $\Delta\theta$ between the true and apparent targets (*Fig. 1*). Actually this "radome error" is not considered serious for the airborne weather radomes now in use. For example, currently radomes with elliptic profiles and length-diameter ratio of about 1 have radome errors on the order of 0.5-1.5 deg.

Sidelobe effects on performance

The antenna pattern can also be described as a graphical plot of the range for constant power return as a function of direction (*Fig. 2*). The range as presented in this plot is normalized with respect to the range in the direction of the beam axis:

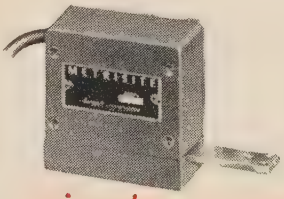
$$R(\theta)/R_{max} = [G(\theta)/G_{max}]^{\frac{1}{4}}.$$

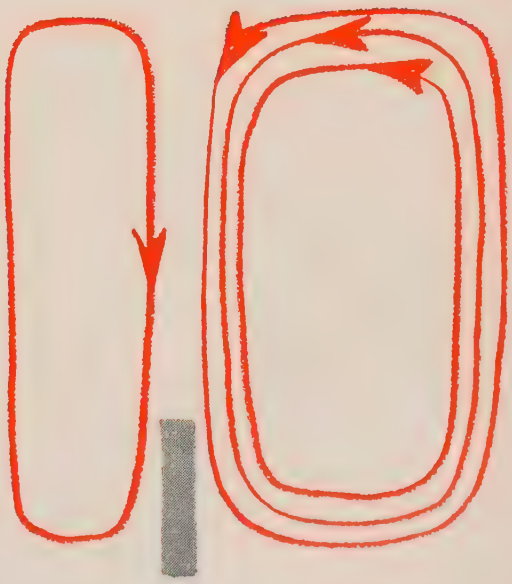
Thus the radar echo from a target located in the direction of a side lobe peak whose power is 20 db below that of the main lobe:

$$\frac{G(\theta)}{G_{max}} = \frac{-20\ db}{2} = -0.1,$$

has the same intensity it would have if the target were located in the direction of the beam axis at a range 10 times greater.

Range gating makes it possible to separate targets in range but not to distinguish main and side lobe returns. Sidelobes greater than 20 db down are typical of weather radar antennas. A three-decibel degradation (side lobe 17 db down) by the radome is acceptable. Side lobe effects are more pronounced when the lobes are directed so that large amounts of power are radiated toward the ground. Returns from these lobes can put "ghost clouds" on the display when the weather is clear, and they can also clutter true weather presentations.—End

Metrisite... is the only device available today that provides a near-perfect combination of **ideal** transducer characteristics. The unusual properties of this remarkable new motion-sensing development are: **extreme resolution**...  easily measures one ten-millionth of an inch; **minute operating force**... absolute minimum bearing friction; **negligible reactive force**... a fraction of a milligram; **true linearity**... a proven accuracy of 1/10%; **high electrical output**... up to 100 volts without amplification; **wide range of shapes and sizes**... from sub-miniature on up; **exceptional ruggedness**... can meet military shock and vibration tests. Now, many of the obstacles that have plagued control technology can be eliminated. Write for **Metrisite** details.



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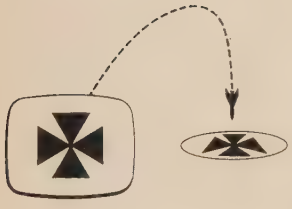
design digest

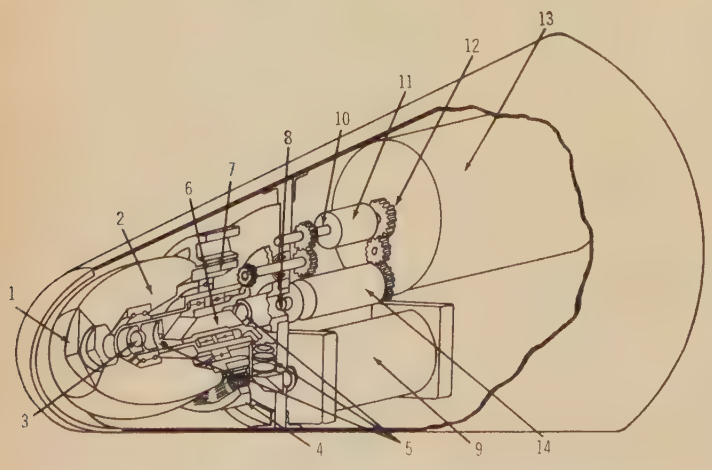
Opto-electronic guidance for air-to-ground



by Bernard Kovit
Associate Electronics Editor

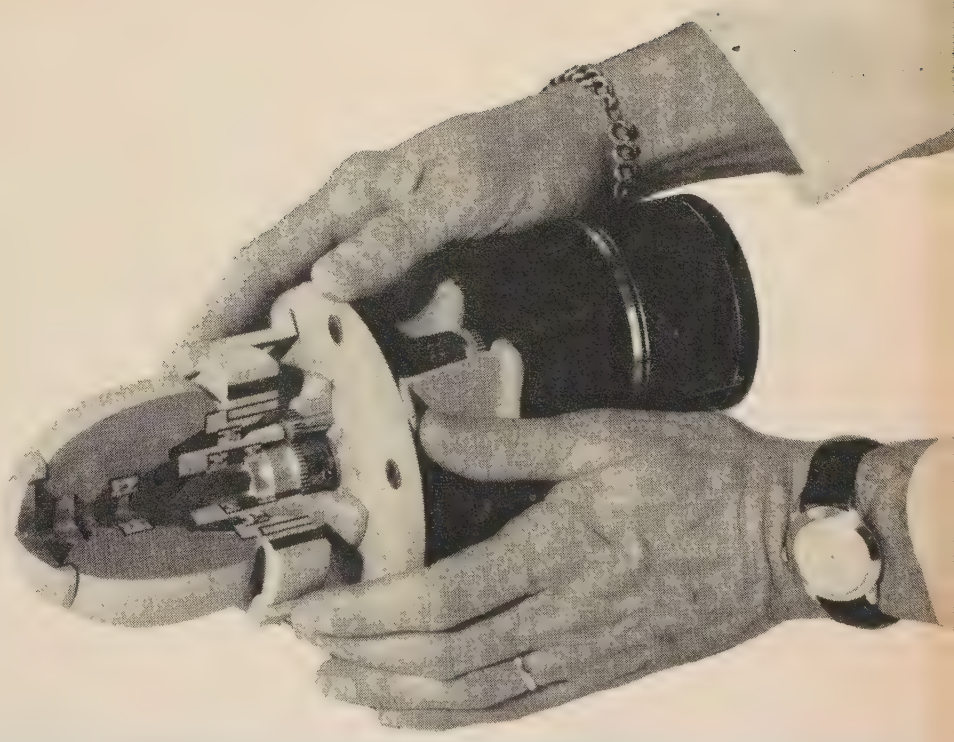
SOLO (*S*elective *O*ptical *L*ock-*O*n) guidance system for air-to-ground missiles, manufactured by Chicago Aerial Industries, Inc., 1980 Hawthorne Ave., Melrose Park, Ill., uses an angular motion detector that produces an electrical error signal when the target at which it is originally aimed shows any angular motion across the field of view. Following these error signals, a servo system keeps Solo's optical axis lined up with the initial target reference. Because Solo's accuracy is always relative to its field of view at initial lock-on, CAI proposes adding TV and a data link command system to let a remote operator (either in the mother plane or on the ground) lock the missile on target from closer in. Compared with inertial systems, Solo is more accurate at all ranges, considerably smaller, weighs less, and costs less, CAI claims. Write in No. 74 on Reader Service Card for more information.

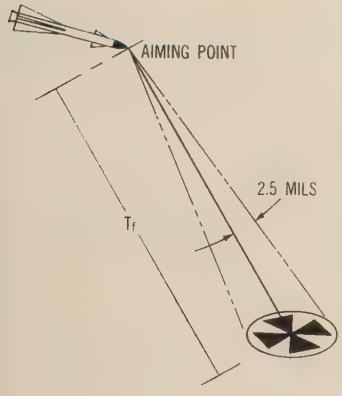
SOLO'S OPTICS are combined with elements of a stable platform that senses and compensates for the yaw, pitch, and roll motions of the vehicle and the optics relative to the original sighting reference. The original target image is acquired and held as a precise reference by imaging lenses that present it to a scan device that integrates the ambient light level and contrast pattern. Associated electronics set up a stable null position to keep the pattern in its relative position within the field of view. The electronic system's outputs are used in servo loops to keep the optical axis of Solo aligned with the original target image.

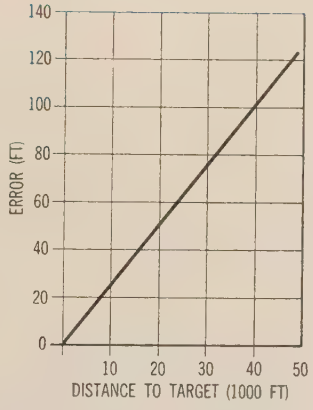


(1) f/1.2 objective lens
(2) Yaw-Pitch gyro
(3) Primary image and field lens
(4) Gyro motor stator
(5) Relay lenses (3 groups)
(6) Derotation prism
(7) Gyro motor rotor
(8) Control signal sensor
(9) Vidicon
(10) Drive train (roll gyro to prism)
(11) Gyro aligning clutch
(12) Drive train (motor to clutch)
(13) Roll gyro
(14) Scan motor

MOCKUP — At present, the guidance system weighs about 15 lb. The electronic control package in the aircraft measures about 6 x 7.5 x 15 in. and uses a six-inch-diameter, 13-in.-long indicator. CAI believes Solo guidance could be used for lobber vehicles or short-range surface-to-surface missiles as well as air-to-ground. The system gets its guidance information from the most accurate and reliable sources — the target area. Flight tests of a prototype of the angular motion detector in Solo showed it could recognize and hold a target with great accuracy.







IMPACT ERROR of Solo is a function of target range from the aiming point (at launch). Compared with inertial systems, Solo is mechanically simpler and requires no extremely precise or complex components.

Solo Performance Specs

Accuracy: Circular probable error (CEP) of 1.5 mil with four-mil field of view

Sensitivity: System can detect contrasts in either natural or man-made structures or terrain features at illumination levels down to five foot-lamberts.

Altitude: Up to 40,000 ft (in standby, up to 80,000 ft)

Maximum Release Distance: Any distance at which pilot can see target area

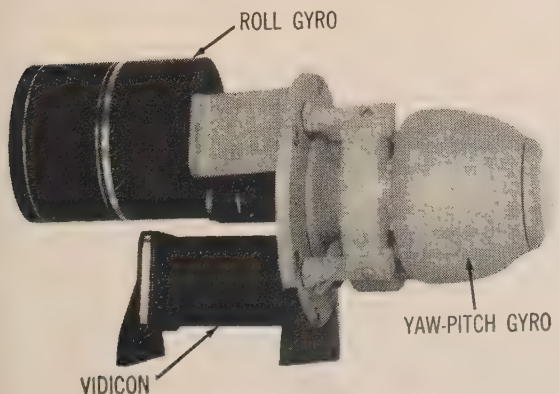
Duration of Flight: Missile flights of at least 50 sec or more, depending on power.

Range of Angular Deflection from Line of Sight: Gyro-stabilized sensor holds target despite angular deflections of the missile up to 18 deg in any direction from line-of-sight (optical axis).

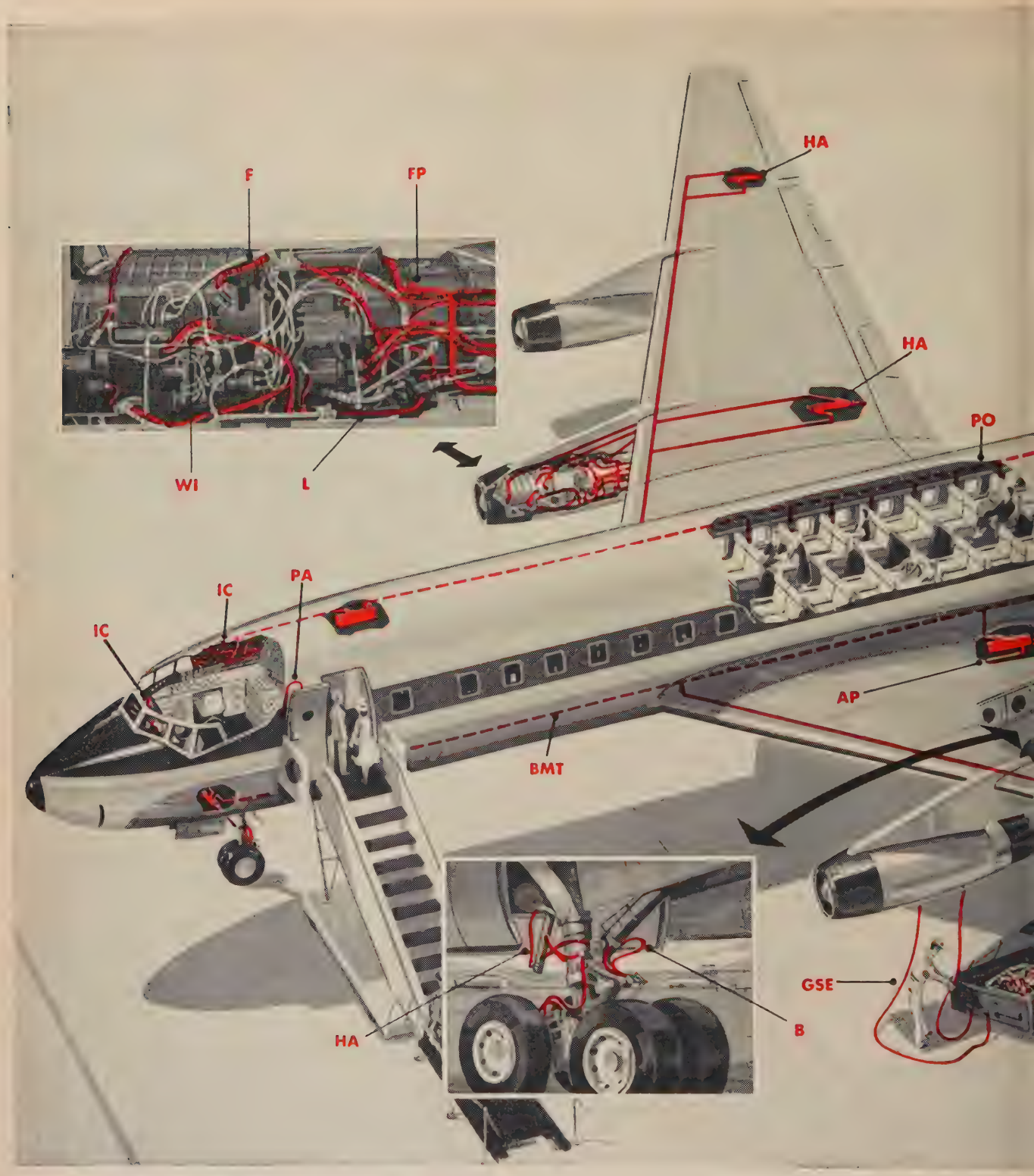
Power Requirements:

(1) Electric input of 28 V dc (nominal) for the instant of initial aiming to burst not exceeding 20 W.

(2) Pneumatic input of one cubic inch of air at 2000 psi. (An alternate design, using an input of 80 W at 115 V, 400 cps before launch to bring gyros to speed, needs no compressed air.)



CAI ENGINEERS are confident of achieving a working prototype of the Solo mockup (left). At present, system is on breadboard. CAI undoubtedly is aiming at Martin's Bullpup and White Lance.



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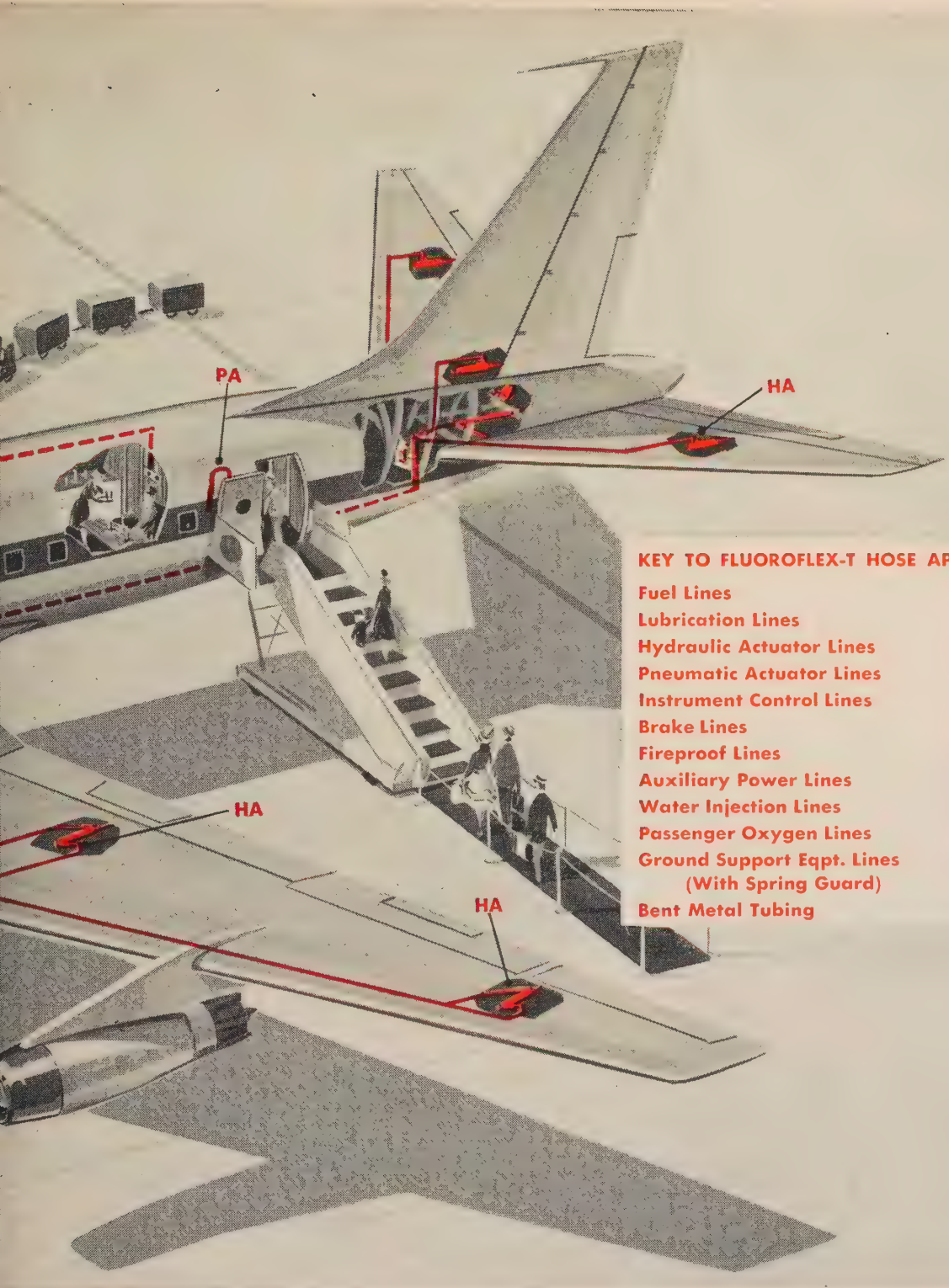

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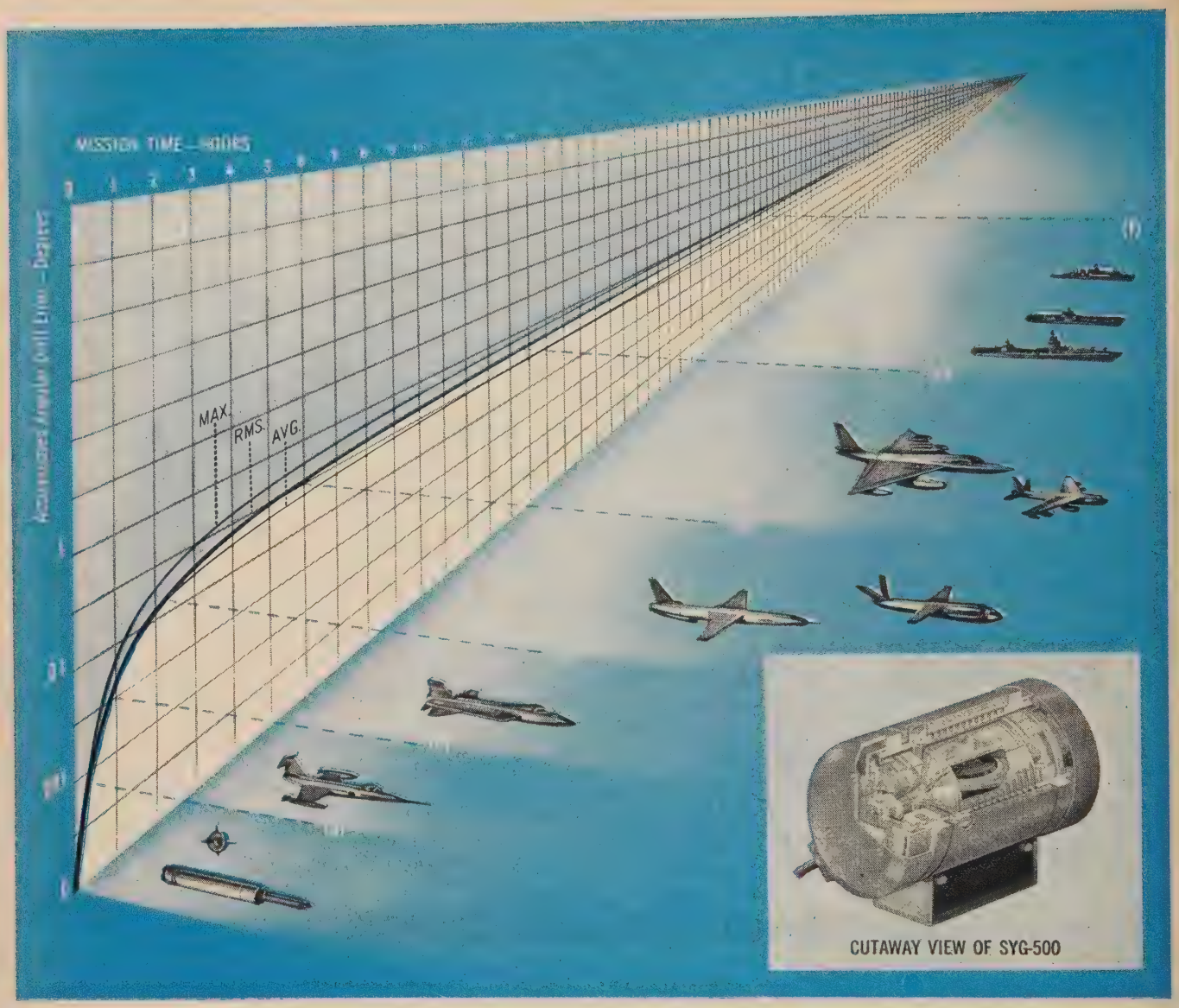

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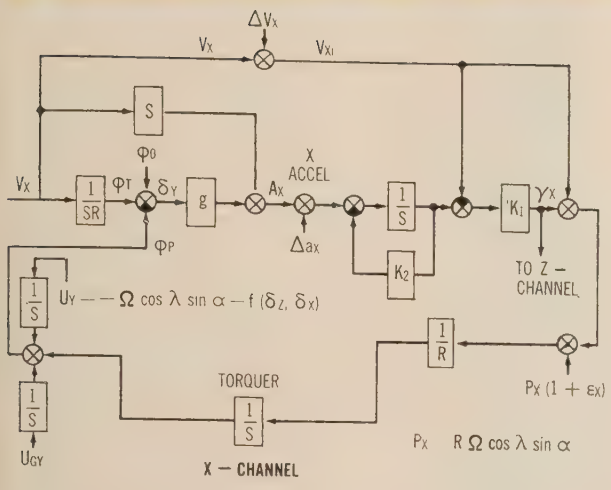

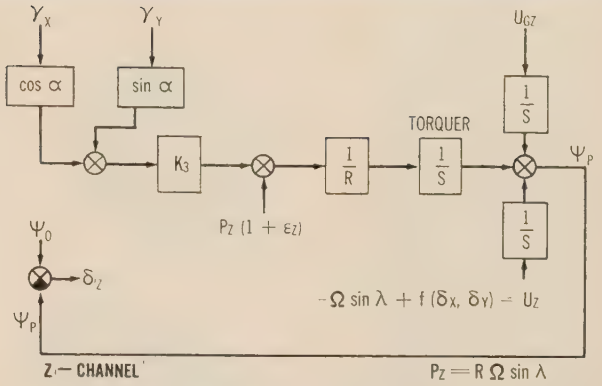

FIGURE 1: Simplified functional diagrams of the X- and Z-channels. The gyro and gimbal dynamics are assumed to have a unity transfer function.

Alignment trade-offs for in-motion

inertial platforms

Inertial platform alignment is touchy enough if your system is in a static ground-based vehicle. But what if the vehicle is on a pitching ship or being buffeted by wind gusts on the launching pad? Here is a method for doing the aligning job even under such conditions and a procedure for predicting the speed and accuracy with which it can be done.

by James E. Vaeth, Design Specialist, Electronics Div., The Martin Co.*

PREFLIGHT alignment dynamics, always important for the design of an inertial navigation system, are particularly critical when the inertial platform is carried by a vehicle that is not stationary during alignment—flying boats, carrier-based aircraft, submarine- and air-launched missiles, space probes subjected to prelaunch wind gusts, and the like. An analysis of the single-degree-of-freedom dynamics for an inertial platform leveling loop has already been made by Bernard Lee, of Emerson-Electric (see *S/A, "Simplified Dynamics for Easier Inertial Design," Oct. '59, p. 191*). A Martin study program has extended this analysis to include the effects of cross-coupling between all three axes—the two leveling channels and the azimuth alignment channel.

This study resulted in an optimized functional design that has been checked out in a three-axis analog simulation program including the gyro-compassing technique. This method is particularly effective for use with inertial systems mounted in ground-launched tactical vehicles —since there are no vehicle velocity disturbances, system gain can be set high enough to damp out initial level and azimuth misalignments within a few minutes. Considerably longer settling times are required in airborne or water-based vehicles because of the possibility of gust and sea-state disturbances.

more on next page

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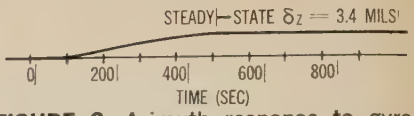

FIGURE 2: Azimuth response to gyro drift rate. Error assumptions— $\lambda = \alpha = 0$ deg, $K_1 = 110$, $K_2 = 0.0155$, $K_3 = 45$, $U_c = U_{GY} = U_{GZ} = 0.5$ deg/hr.

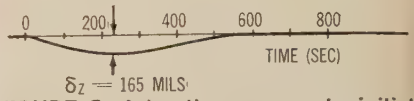

FIGURE 3: Azimuth response to initial level error. Error assumptions— $\alpha = \lambda = 0$ deg, $K_1 = 110$, $K_2 = 0.0155$, $K_3 = 45$, $\phi_0 = \Theta_0 = 4.0$ mils.

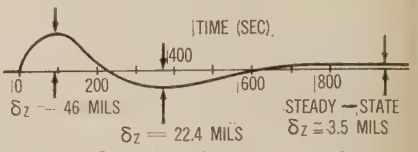

FIGURE 4: Azimuth response to constant velocity error. Error assumptions — $\alpha = \lambda = 0$ deg, $K_1 = 110$, $K_2 = 0.0155$, $K_3 = 45$, $\Delta V_x = \Delta V_y = 5.0$ fps.

Our study sought to establish a quantitative basis for determining the speed and accuracy of self-orientation of an inertial platform about its three gimbal axes as functions of initial conditions and vehicle motion. Because azimuth orientation is based on the gyrocompass principle—any variation in azimuth alignment changes the earth-rate components along the horizontal platform axes—the alignment procedure is self-operative to the extent that only vehicle velocity signals and latitude are needed.

Azimuth alignment error was studied

We were particularly interested in the transient behavior of the azimuth alignment error, which is closely coupled to the leveling errors. The azimuth transient effect could be critical in a tactical situation in which the carrying vehicle is subjected to gust or periodic disturbances. For instance, azimuth alignment to within one mil (0.001 radian) is required to navigate 1000 miles with a terminal accuracy of one mile. If you want to gyro-compass your system to this accuracy, at least one of its three gyros on the platform must have a random drift rate of less than 0.01 deg/hr at 50 deg latitude, where:

NOMENCLATURE

A_X, A_Y	accelerations sensed by the X- and Y-accelerometers, respectively
K_1, K_3	block diagram gains
K_2	damping constant
P_X, P_Y, P_Z	earth's rate corrections generated electrically and used to slave the gyros to the earth's reference for the X-, Y-, and Z-channels, respectively
R	radius of the earth $= 2.1 \times 10^7$ ft
S	Laplacian operator (equivalent to d/dt in Figure 1 $= 7.3 \times 10^{-5}$ rad/sec./)
U_{GX}, U_{GY}, U_{GZ}	gyro drift rate signals used as inputs to the X-, Y-, and Z-gyros, respectively
U_X, U_Y, U_Z	earth-rate components physically sensed by the X-, Y-, and Z-gyros, respectively
V_X, V_Y	true velocities of the X- and Y-channels, respectively
V_{Xi}, V_{Yi}	external velocity information relative to the earth, including possible errors in the X- and Y-channels, respectively
g	earth's gravitational acceleration $= 32.2$ ft/sec^2
ΔV_X, ΔV_Y	errors in true velocity in the X- and Y-channels, respectively
Δa_X, Δa_Y	bias errors in the X- and Y-accelerometers, respectively
Ω	angular velocity of the earth with respect to inertial space
α	desired azimuth angle measured positive and clockwise from North
γ_X, γ_Y	electric quantities derived from a comparison between an externally derived velocity and an integrated accelerometer output for the X- and Y-channels, respectively (used as inputs to the azimuth channel)
δ_X, δ_Y	errors in the vertical for the X- and Y-channels, respectively
δ_Z	error in the azimuth as indicated in the Z-channel
ϵ_X, ϵ_Y, ϵ_Z	instrumentation errors incurred in generating P_X, P_Y, and P_Z, respectively
λ	angle of latitude
ϕ_0, θ_0	initial departure of the platform from alignment, contributing to errors in the verticals of the X- and Y-channels, respectively
ϕ_P, θ_P, ψ_P	actual angular positions of the stable platform for the X-, Y-, and Z-channels, respectively
ϕ_T, θ_T	central angles traversed by the vehicle from an initial position to a subsequent position, measured at the earth's center for the X- and Y-channels, respectively
ψ_0	initial departure from alignment, contributing to error in the azimuth
ω	vehicle forcing frequency

error = drift rate/earth rate × cosine λ.

This error is too often considered the limiting criterion. When time is a consideration and the vehicle is not rigidity-fixed to the ground, errors much greater than one mil can occur even with perfect gyros. In such a situation, gyro-compassing is especially attractive and optical azimuth alignment is least attractive.

We analyzed the transient azimuth alignment error in a two-phase study. The preliminary analysis led to our optimized functional design; in the subsequent analog-computer phase, we checked this design and made a comprehensive study of dynamic effects.

Figure 1 shows the *X*- and *Z*-channels and *Figure 5*, the gimbal geometry. The *Y*-channel is similar to the *X*-channel.

The results were plotted for system gain settings

Table I defines the level and azimuth errors as functions of the Laplacian operator (*S*). We felt that deriving expressions for δ_X, δ_Y, and δ_Z in the time domain for

more on next page

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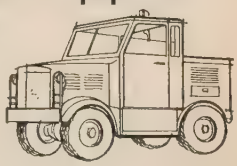

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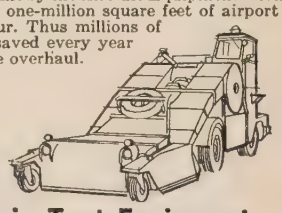

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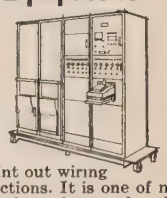

Automatic multiple circuit analyzers similar to the one shown have been built by Consolidated Avionics for major electronics and missile manufacturers. They search more than 2,000 points in a system and point out wiring errors and doubtful connections. It is one of many highly specialized electronic units produced by Avionics. Other products include data reduction systems and a complete line of transistorized power supplies.

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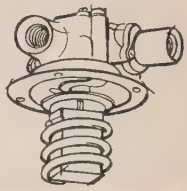

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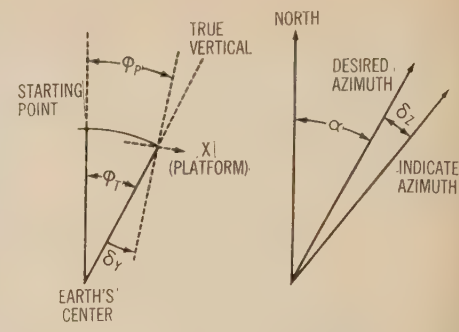

FIGURE 5: Gimbal geometry.

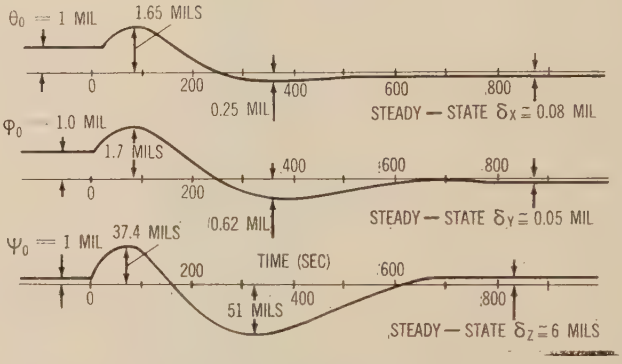

FIGURE 6: Typical three-channel response plot. Error assumptions —$\lambda = \alpha = 0$ deg, $K_1 = 110$, $K_2 = 0.0155$. $K_3 = 45$, $\Delta a_X = \Delta a_Y = 10^{-5}$ g, $\Delta V_X = \Delta V_Y = 5.0$ fps, $E_X = E_Y = E_Z = 10^{-3}$, $U_{GX} = U_{GY} = U_{GZ} = 0.05$ deg/hr.

Table I: Alignment Error Equations

For X-Channel:

$$\left(S^2 + K_2S + \frac{K_1 g}{R}\right)\delta_Y = S(S + K_2)\phi_0 + \frac{K_1 S}{R}\Delta V_X + (S + K_2)\left[-\frac{\Delta V_X}{R} - \Omega\cos\lambda\sin\alpha(1 + \epsilon_X) + \Omega\cos\lambda\sin\alpha + \delta_Z\,\Omega\cos\lambda\cos\alpha + \delta_X\,\Omega\sin\lambda - U_{GY}\right] - \frac{K_1}{R}\Delta a_X$$

For Y-Channel:

$$\left(S^2 + K_2S + \frac{K_1 g}{R}\right)\delta_X = S(S + K_2)\theta_0 + \frac{K_1 S}{R}\Delta V_Y + (S + K_2)\left[-\frac{\Delta V_Y}{R} + \Omega\cos\lambda\cos\alpha(1 + \epsilon_Y) - \Omega\cos\lambda\cos\alpha + \delta_Z\,\Omega\cos\lambda\sin\alpha - \delta_Y\,\Omega\sin\lambda - U_{GX}\right] - \frac{K_1}{R}\Delta a_Y$$

For Z-Channel:

$$\left(S^3 + S^2K_2 + \frac{SK_1 g}{R} + \frac{gK_1K_3\Omega\cos\lambda}{R}\right)\delta_Z = S\left(S^2 + K_2S + \frac{K_1 g}{R}\right)\psi_0 - \frac{K_3}{R}\left\{gK_1S\,\phi_0\cos\alpha + gK_1S\,\theta_0\sin\alpha - K_1S^2\cos\alpha\,\Delta V_X - K_1S^2\sin\alpha\,\Delta V_Y + gK_1\cos\alpha\left[-\frac{\Delta V_X}{R} - \Omega\cos\lambda\sin\alpha(1 + \epsilon_X) + \Omega\cos\lambda\sin\alpha + \delta_X\,\Omega\sin\lambda - U_{GY}\right] + gK_1\sin\alpha\left[-\frac{\Delta V_Y}{R} + \Omega\cos\lambda\cos\alpha(1 + \epsilon_Y) - \Omega\cos\gamma\cos\alpha - \delta_Y\Omega\sin\lambda - U_{GX}\right] + K_1S\,\Delta a_X\cos\alpha + K_1S\,\Delta a_Y\sin\alpha\right\} - \left(S^2 + K_2S + \frac{K_1 g}{R}\right)\left[\Omega\sin\lambda(1 + \epsilon_Z) - \Omega\sin\lambda + \delta_X\Omega\cos\lambda\sin\alpha + \delta_Y\,\Omega\cos\lambda\cos\alpha + U_{GZ}\right]$$

simultaneous input disturbances was too cumbersome and gained valuable time by limiting this phase of the study to single forcing errors of initial orientation and velocity. In this way, we solved the simultaneous set of equations, transformed it into the time domain, and plotted it for a limited number of system gain settings. The important conclusions we were able to

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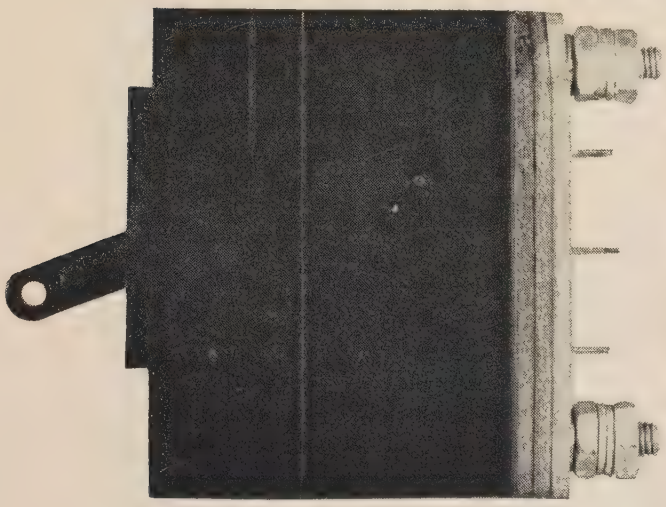

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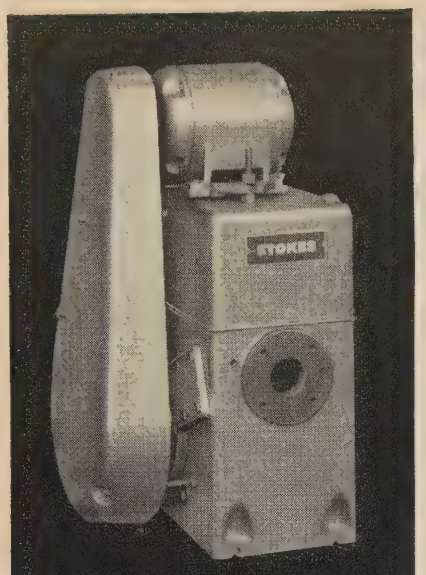

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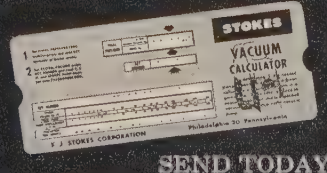

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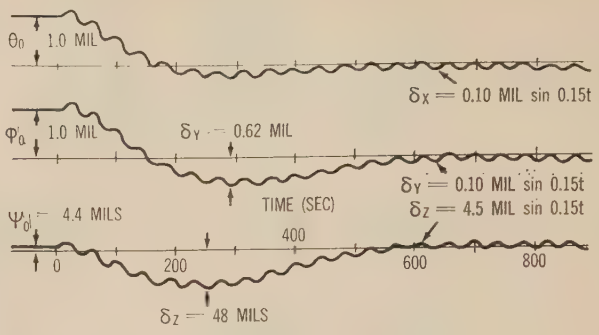

FIGURE 7: Response to sinusoidal motion of vehicle. Error assumptions are the same as for Figure 5, except for $\Delta V_x = \Delta V_y = 3$ fps sin 0.15t and $\Delta a_x = \Delta a_y = 10^{-4}$ g.

draw from this analytical study are:

- The system transient behavior can be optimized for any desired value of settling time (a function of $K_1^{-\frac{1}{2}}$) by the selection of K_2 and K_3, which is a matter of controlling the roots of the cubic expression in the Z-channel equation.
- The leveling errors are only slightly affected by errors in the azimuth channel.
- The magnitude of the azimuth error (δ_Z) is a significant function of inaccuracies in the leveling loops.

Good correlation with the preliminary analysis

We simultaneously mechanized the X- and Z-channels and the second leveling loop (Y-channel) on an analog computer. The problem we set up allowed us to vary K_1, K_2, K_3, λ, and α, and all the inputs shown in *Figure 1*, including, sinusoidal as well as step ΔV inputs. *Figure 6* shows a typical response plot. From the start, we got good correlation with the transient plots from the preliminary analysis phase, including the expected steady-state errors. The important results of the computer study were:

- For an optimum combination of K_1, K_2, and K_3, the single-channel approximation is quite adequate for the level axes, but not for azimuth alignment. Moreover, the level errors are insignificant in comparison with the azimuth errors.

K_3 should be varied as a function of $1/\cos\ \lambda$

- To preserve optimum dynamic response for all operating latitudes, K_3 should be varied as a function of $1/\cos\ \lambda$ to hold K_1 and K_2 constant.
- The azimuth steady-state error depends almost entirely on the steady-state magnitudes of level-axis-gyro drift, velocity measurement error, and latitude. Computing from the Z-channel equation we found that this error amounts to 0.65 mil of azimuth misalignment at the equator for $\Delta V = 1$ fps or $U_d = 0.01$ deg/hr and varies as $1/\cos\ \lambda$.

more on page 190

Table II:
Typical Computer Results

Disturbance	K_1	K_2	K_3	δ_Z Peak (mils)	Settling Time (sec δ_Z = steady state ± 1 mil)
Φ_0 = 4 mils	1400	0.065	160	660	480
Φ_0 = 4 mils	110	0.0155	45	175	660
Φ_0 = 18 mils	110	0.0155	45	775	670
ΔV = 5 fps	350	0.03	80	130	400
ΔV = 5 fps	110	0.0155	45	46	700
ΔV = 5 fps	50	0.0105	30.2	20	0100
				δ_Z oscillation*	δ_Y oscillation*
$\Delta V = 3 \sin 0.15t$	110	0.0155	45	4.6	0.1 mils
$\Delta V = 3 \sin 1.5t$	110	0.0155	45	0.45	0.01 mils
$\Delta V = 3 \sin 1.5t$	1400	0.065	160	22	0.13 mils

*Denotes half amplitude of steady-state oscillation. For these runs, $\lambda = \alpha = 0$ deg.

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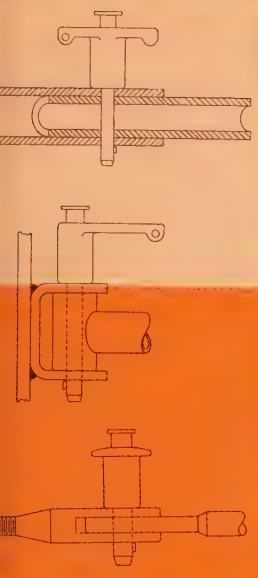

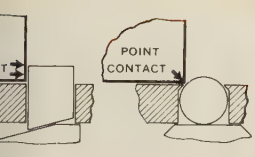

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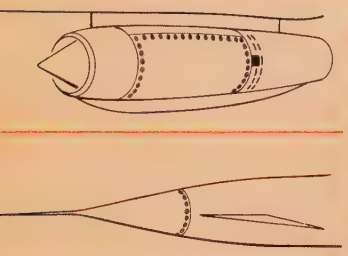

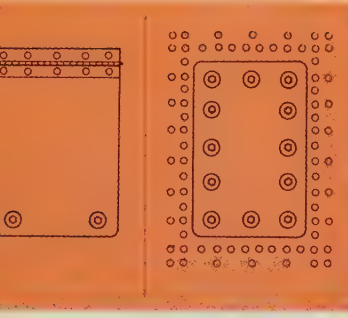

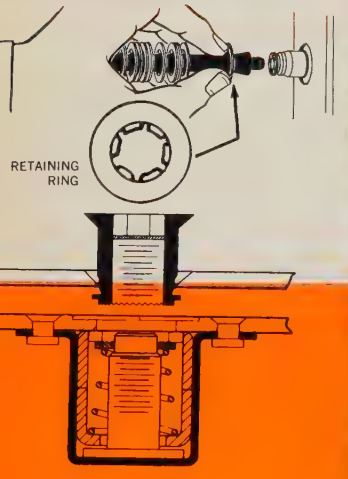

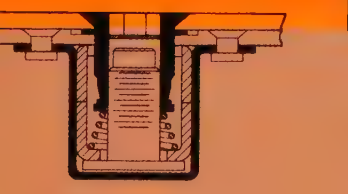

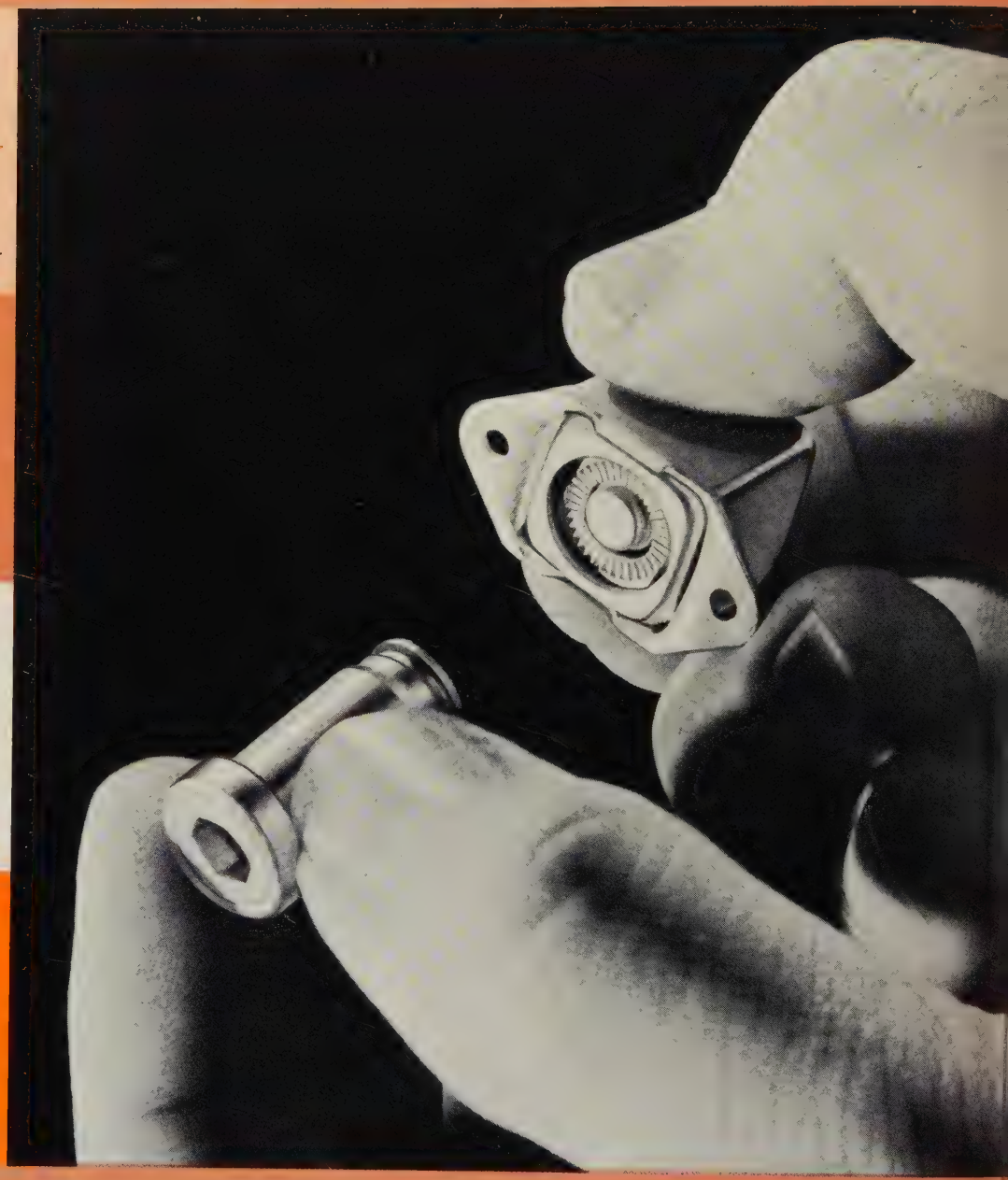

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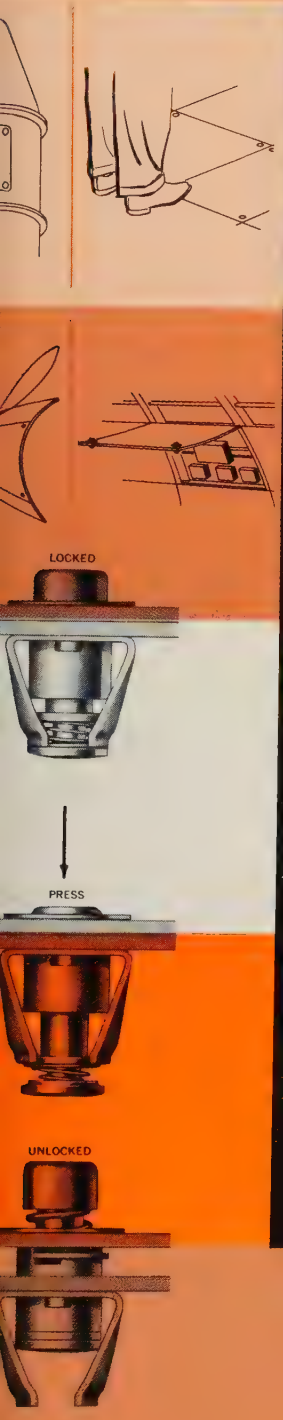

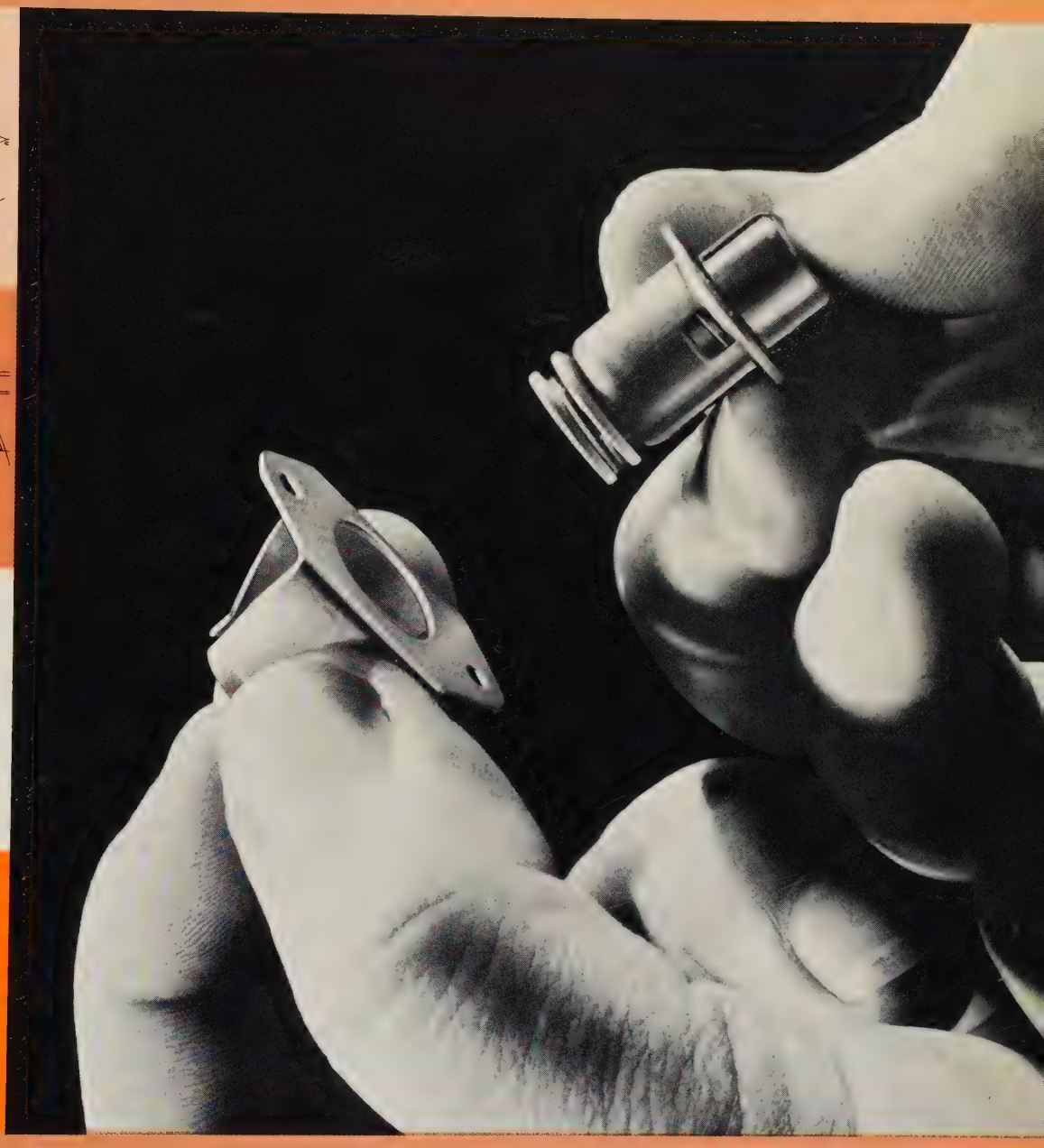

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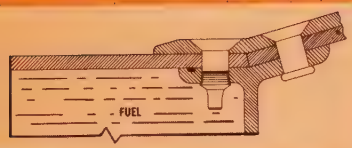

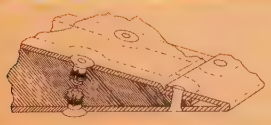

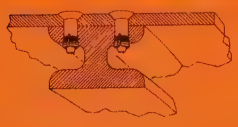

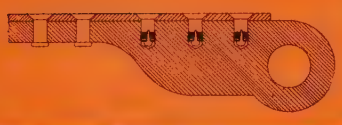

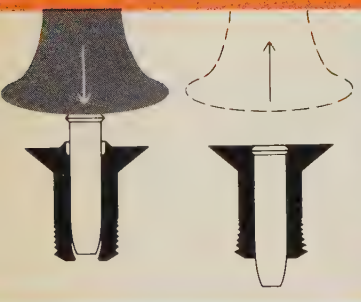

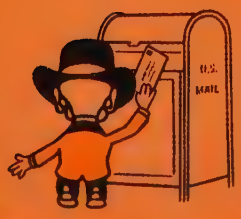

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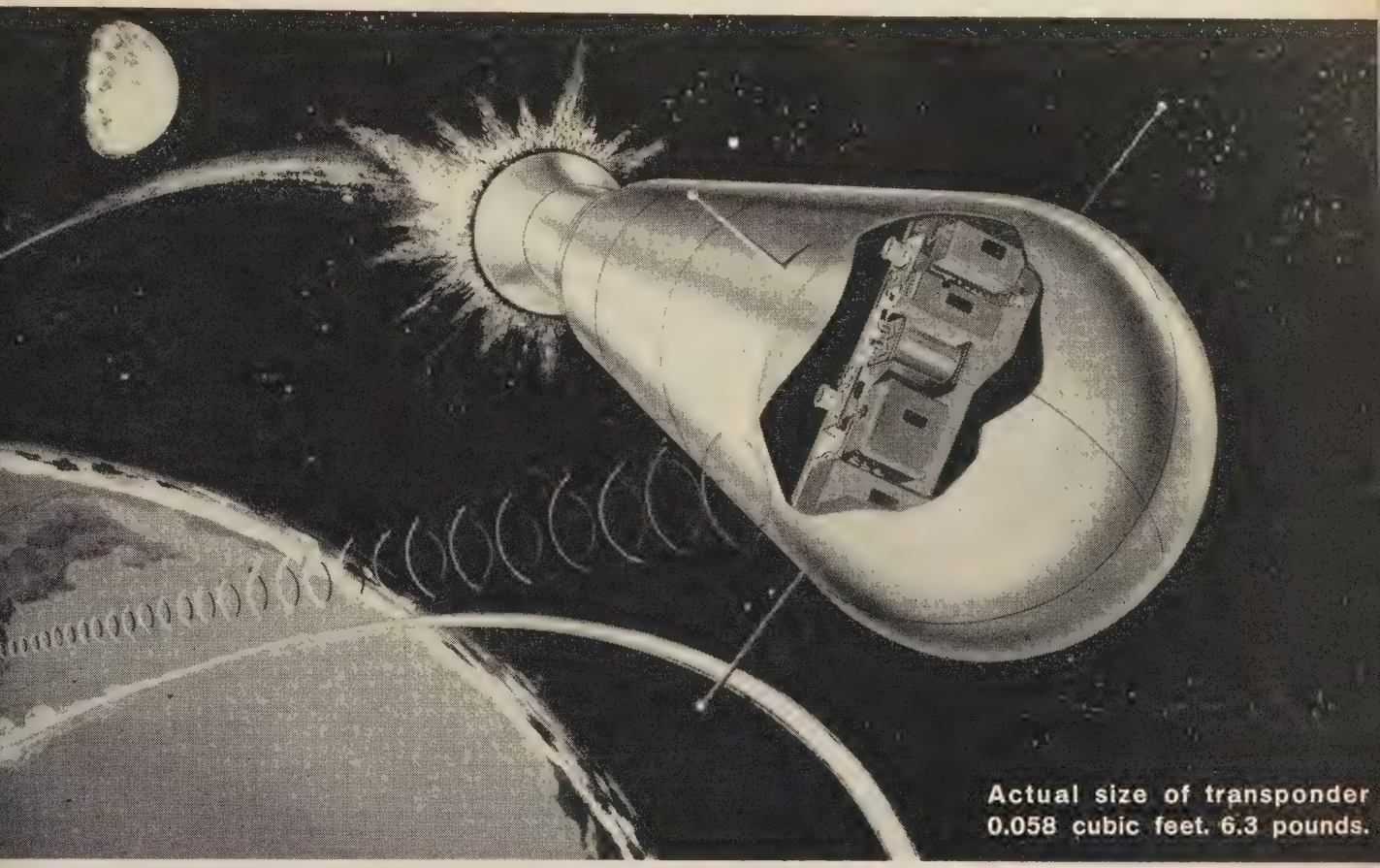

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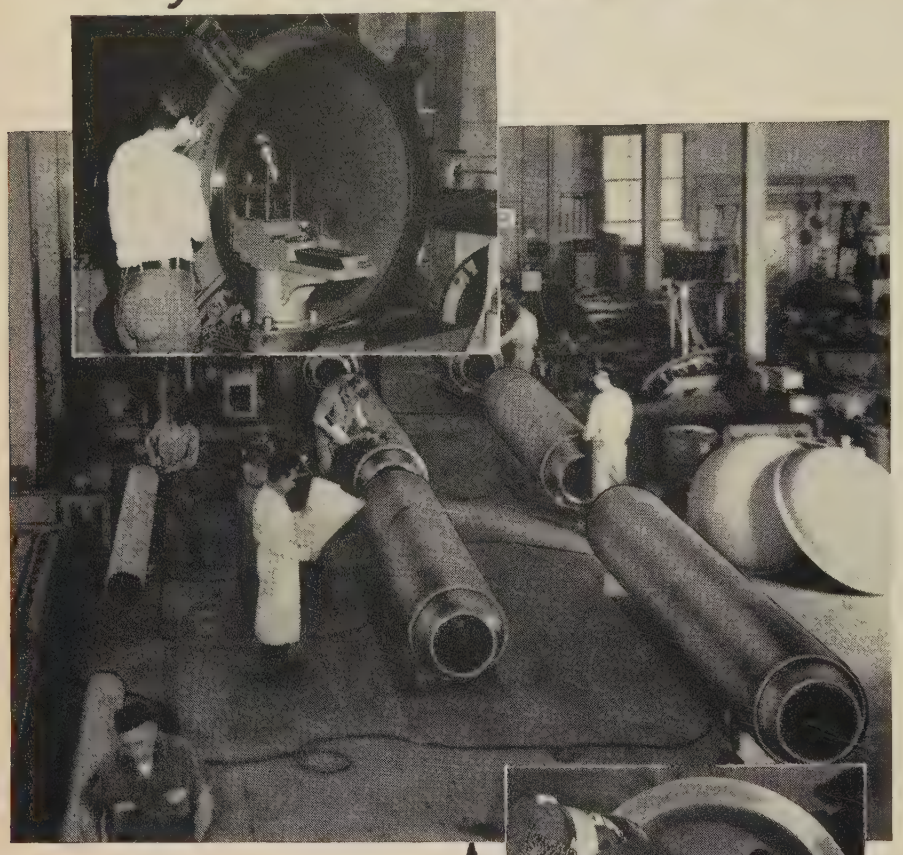

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• Gyro drift and errors in earth-rate compensation (ϵ) have negligible dynamic effects. *Figure 2* shows that considerable time must pass before the system reacts to a step input in the drift rate.

Initial azimuth misalignment is negligible

• Concurrent application of input errors and disturbances produced no critical or unexplainable effects of either a dynamic or a steady-state nature. The error contributions, we found, were almost directly additive.

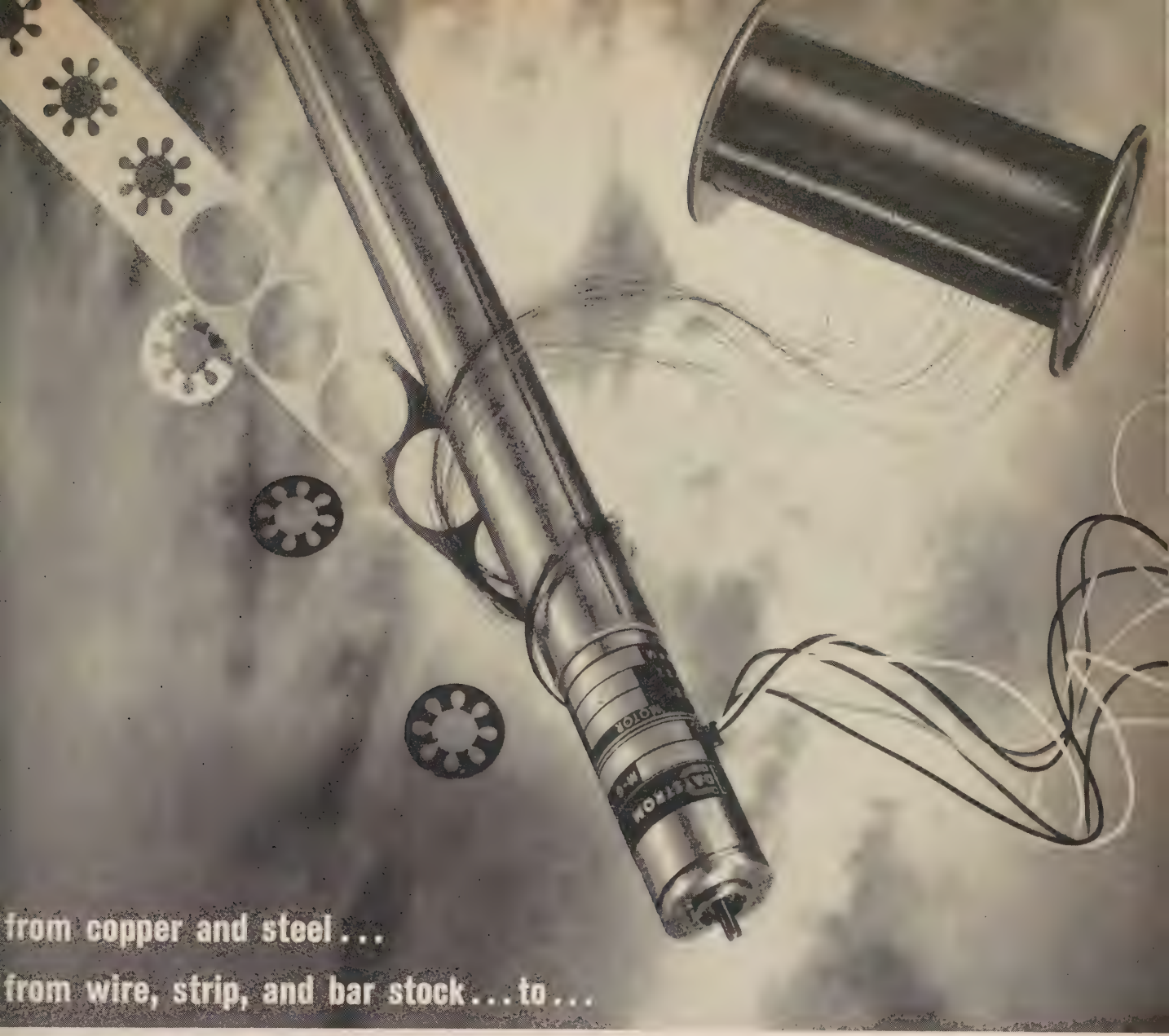
• Initial azimuth misalignment (ψ_o) has negligible dynamic effects. However, initial level misalignment (ϕ_o), though it causes no steady-state errors, causes sizable transient errors in azimuth (*Fig. 3*). Table *II* lists the peak over-shoot and time for δ_Z to damp to less than one mil for various values of ϕ_o and system gain. We found that the magnitude of the peak over-shoot in δ_Z varies as ϕ_o and $K_1 ½$. Other computer runs showed that an accelerometer bias error of 10^{-4} g would cause an azimuth response equivalent to that for $\phi_o = 0.1$ mil.

• A steady-state error in vehicle velocity measurement leads to a sizable overshoot in δ_Z (*Fig. 4*). We found that peak overshoot varies directly as $_AV$ and K (*Table II*).

The vehicle motion should be compensated for

• Unless compensated, the motion of the carrying vehicle significantly prolongs the settling time. We used a sinusoidal velocity error to simulate typical vehicle disturbances due to sea state or gusts (*Fig. 4*). Numerous computer runs confirmed that, for $\omega > (K_1 g/R) ½$ the peak value of δ_Z varies as $\Delta V K_1 K_3/\omega$, whereas that of δ_Z varies as $\Delta V K_1/\omega$. If therefore the disturbing motion can be approximated (though not compensated) the system gain can be set so that the δ_Z oscillation will not exceed the azimuth accuracy requirements.

From these results we concluded that gyro-compassing at sea or in the air requires either a long settling time (perhaps Schuler-tuning for which K_1 must equal 1) or some means of compensation (like filtering). Whether compensation is feasible depends on the characteristics of the mission to which it is to be applied.—End



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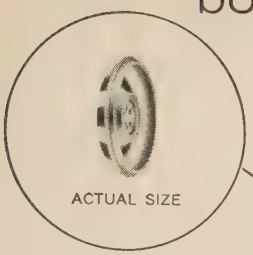
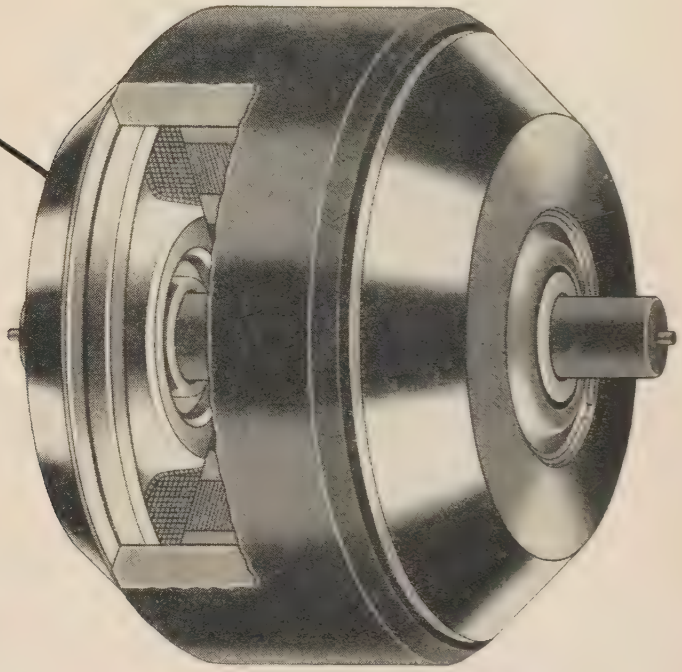
BARDEN end-bell bearings boost miniature gyro performance – reduce assembly time and cost





Integral design simplifies manufacture, reduces mating-part errors

Z155, *above and in main illustration,* is one of several Barden Precision end-bell bearings currently in volume production. Bore sizes range from .0781" to .1250" for through-bored rotor rings from .5751" to .9375" I.D. For complete technical information, write for Engineering Data Sheet Z-1.

Rotor bearings for miniature rate gyros in missile stabilizing systems must meet extremely high performance requirements, yet allow economical production and assembly. To solve this problem, Barden pioneered special configuration, high precision end-bell bearings.

Pressed into opposite sides of the through-bored rim, these bearings become an integral part of the gyro spin mass while serving as end caps for the gyro wheel assembly. This eliminates delicate fitting of very small bearings into conventional end bells . . . reduces mating-part errors and assembly time . . . improves squareness, concentricity, and overall accuracy and reliability.

One gyro manufacturer reports that the use of Barden Precision end-bell bearings in place of conventional flanged bearings reduced noise levels 50% and made it possible to meet unusually stringent life requirements.

Like other Barden advances in design and production, end-bell bearings solve a specific performance problem. Other Barden Precision bearings satisfy such extreme demands as:

- High temperatures (to 575°F.)
- High speeds (to over 300,000 RPM)
- Low torque (to 10 dyne-cm. for 2 lb. load)
- Concentric rotation (to .00005" max. T.I.R.)

Barden is a major supplier of standard bearings in sizes from .0469" bore to over 3" O.D., all manufactured to Barden Precision standards of dimensional accuracy, uniformity and reliability. See Sweet's Product Design File (8h/Ba) for Barden catalog and bearing selection guide.

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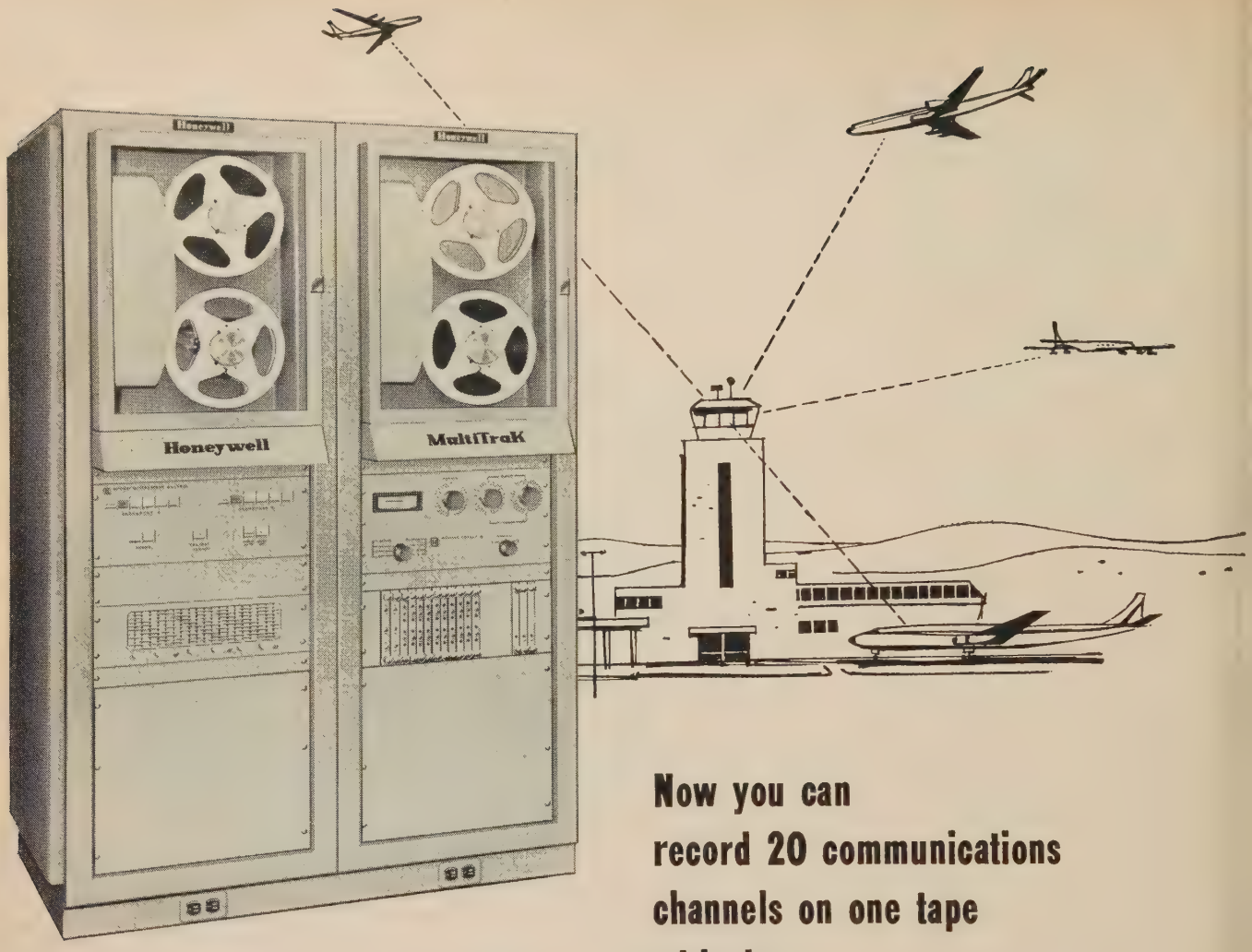

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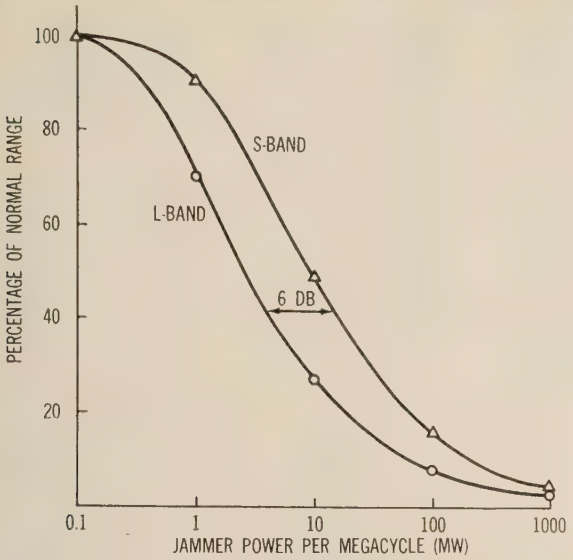

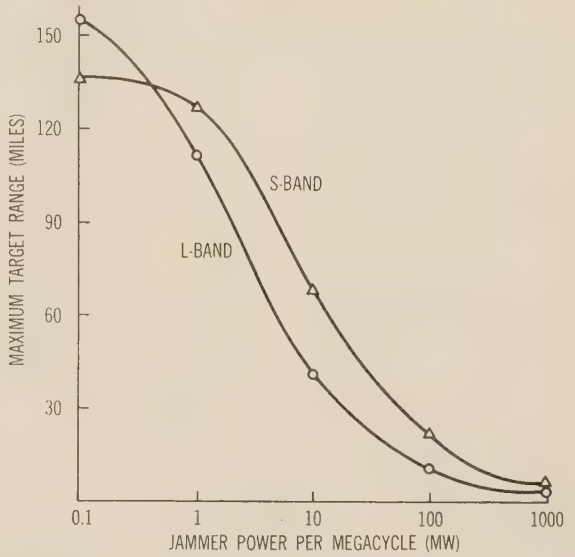

FIGURE 1: L- and S-band radars under jamming (left). Constant six-decibel abscissa difference between curves shows S-band set is six decibels less susceptible to noise jamming. Right: Performance under jamming obtained by multiplying values of graph at left by maximum radar range. Jammer antenna gain is six decibels. Although the L-band radar has the greater normal range, its range is less under any appreciable jamming.

Simple calculation gives radar's jamming susceptibility

Actual radar detection performance is a matter of statistics and depends on many parameters. However, reasonable "ballpark" estimates of noise jamming effects on overall performance can be made from equations based on the radar range relationship.

by Simon Cohen and George Minty

Chief, Vulnerability Branch, U. S. Army Signal Research & Development Laboratory, & Mathematics Dept., U. of Washington, resp.*

IN EVALUATING the vulnerability of his radar to countermeasures, the radar designer is particularly interested in finding out just how susceptible his system is to noise, the form of jamming the radar probably will see most often. His analysis in this case considers only the effect of an interfering signal on the electronics components of the system. It takes into account three factors:

- the countermeasures that will affect the system;
- the effects on the components of the systems;
- the J/S (jammer-to-signal) ratio required at the inputs to the components if the countermeasures are to be effective.

* U.S. Army Signal Research & Development Laboratory, Ft. Monmouth, N.J. This article is a condensation of the Signal Corps Engineering Laboratories Technical Memorandum 1678 ("A Radar Free-Space Noise-Jamming Susceptibility Calculator"). Mr. Minty formerly was a mathematical assistant at USASRDL.

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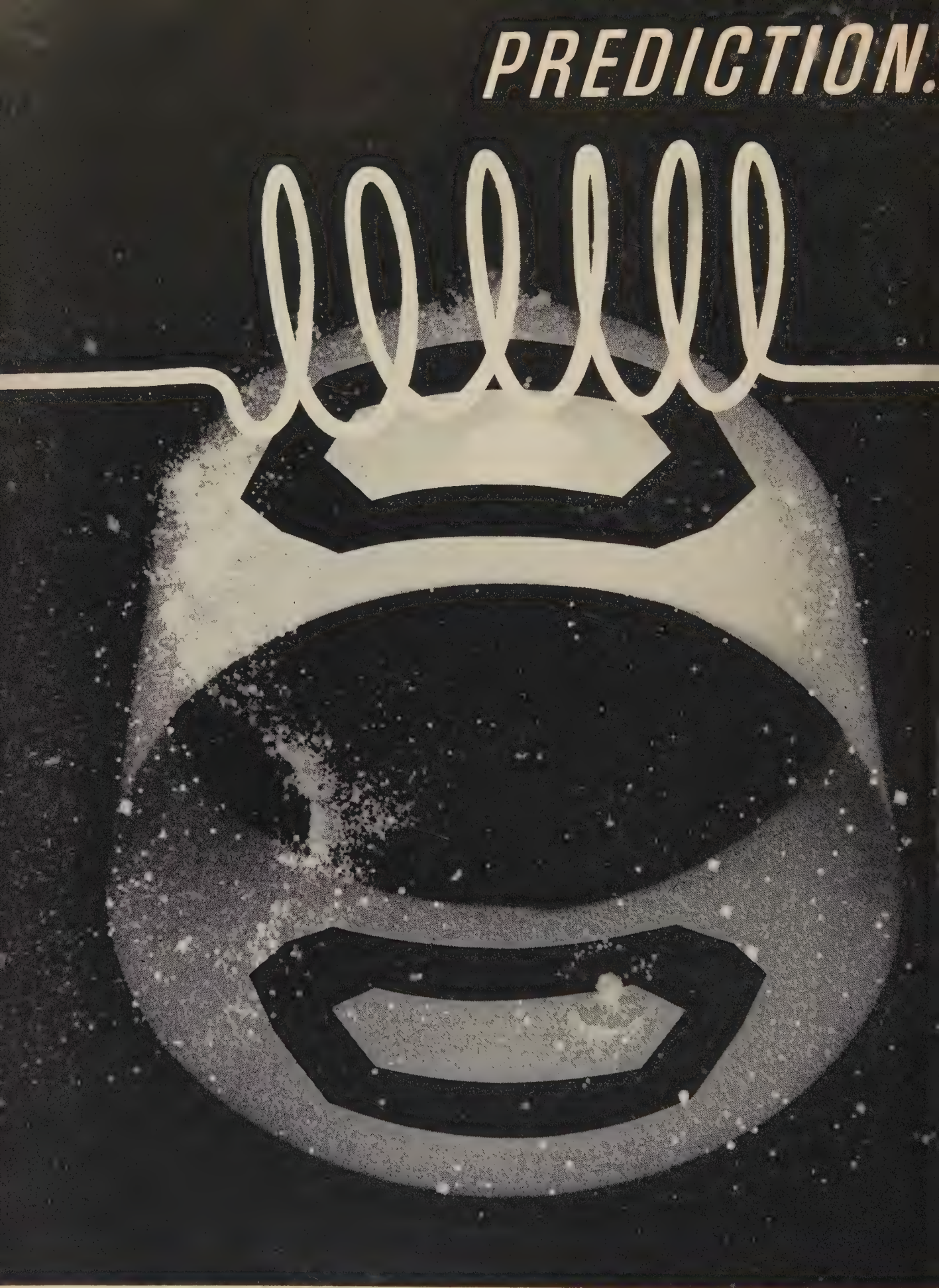

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DEFINITION: Inverse homopolar magnetics, as used here, refers to a unique structure for the rotors of electric motors and generators. Both pole faces are incorporated into a continuous, cylindrical surface. The north polar faces extend radially toward the center of the rotor, serving as flux path and support of the magnetic south polar "shell."

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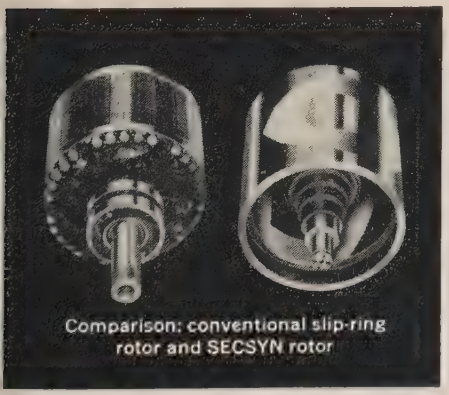

Comparison: conventional slip-ring rotor and SECSYN rotor

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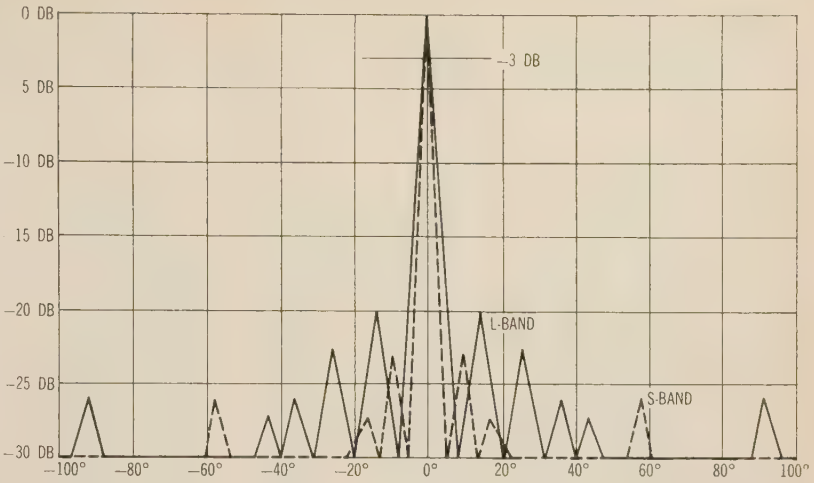

FIGURE 2: Arbitrary antenna patterns on which the contour jamming calculations of Figure 4 are based.

The susceptibility of a radar to noise jamming can be found by calculating the ratio between its range under jamming conditions (R_j) and its range when there is no jamming (R_n). The first step in finding this ratio is the basic radar range equation:

$$(1) \qquad R_n = \sqrt[4]{\frac{P_t G_r^2 \lambda^2 \sigma}{(4\pi)^3 V\overline{NF}kTB}},$$

where P_t is the transmitted pulse power; G_r, the radar's antenna gain; λ, the wavelength; σ, the effective target area; V, a "visibility factor"; NF, the receiver noise figure; B, the radar's IF bandwidth; and KT equals 4×10^{-21} W per cycle. The range of the radar is inversely proportional to the fourth root of the thermal noise power per unit bandwidth at the input of the IF amplifier. Therefore, if we assume that power from the jammer adds directly to the receiver noise power and that the jammer spectrum covers the IF bandwidth, it follows that:

$$(2) \qquad R_j/R_n = \sqrt[4]{P_n/(P_n + p_j)},$$

where R_j is the range under jamming, or the range to which the aircraft under jamming must approach before it can be detected by the radar; P_n, the receiver noise power per unit bandwidth at the IF input; equaling $NFKT$; and p_j, the jammer power per unit bandwidth at the radar's IF input. From the one-way transmission equation, we get:

$$(3) \qquad p_j = \frac{P_j G_j G_r \lambda^2 G_{r\text{-}rel}}{C(4\pi)^2 D^2} \text{ watts per cycle,}$$

where P_j is the jammer transmitter power (in W/mc); G_j, the jammer antenna gain; G_r, the peak gain; $G_{r\text{-}rel}$ (≤ 1), the gain of the radar antenna in the direction of the jammer and relative to G_r; D, the distance from jammer to radar (in miles); λ, the wavelength (in centimeters); and C, a conversion factor (3.02×10^{16} for the units we are using). By substitution into *Equation 2* and simplification, we get:

$$(4) \qquad \frac{R_j}{R_n} = \sqrt[4]{\frac{\dfrac{C(4\pi)^2 \overline{NF}kTD^2}{P_j G_j G_r \lambda^2 G_{r\text{-}rel}}}{\dfrac{C(4\pi)^2 \overline{NF}kTD^2}{P_j G_j G_r \lambda^2 G_{r\text{-}rel}} + 1}}.$$

This is the reduction-in-range formula for a jammer at a distance D from the radar (i.e., a jammer not carried by the target). When the jammer is carried by the target, set $G_{r\text{-}rel} = 1$ and $D = R_j$ in *Equation 4* and solve for R_j/R_n:

$$(5) \qquad \frac{R_j}{R_n} = \sqrt{\frac{-1 + \sqrt{1 + 4\left[\dfrac{C(4\pi)^2 \overline{NF}kTR_n^2}{P_j G_j G_r \lambda^2}\right]^2}}{2\dfrac{C(4\pi)^2 \overline{NF}kTR_n^2}{P_j G_j G_r \lambda^2}}}.$$

The approximations to *Equations 4 & 5* for $p_j << P_n$ and $p_j >> P_n$ are interesting. For $p_j << P_n$, both *Equations* become:

$$(6) \qquad R_j/R_n = 1.$$

For $p_j >> P_n$, they become:

$$(7) \qquad \frac{R_j}{R_n} = \sqrt[4]{\frac{C(4\pi)^2 \overline{NF}kTD^2}{P_j G_j G_r \lambda^2 G_{r\text{-}rel}}},$$

$$(8) \qquad \frac{R_j}{R_n} = \sqrt{\frac{C(4\pi)\overline{NF}kTR_n^2}{P_j G_j G_r \lambda^2}}.$$

From *Equation 1*, we get:

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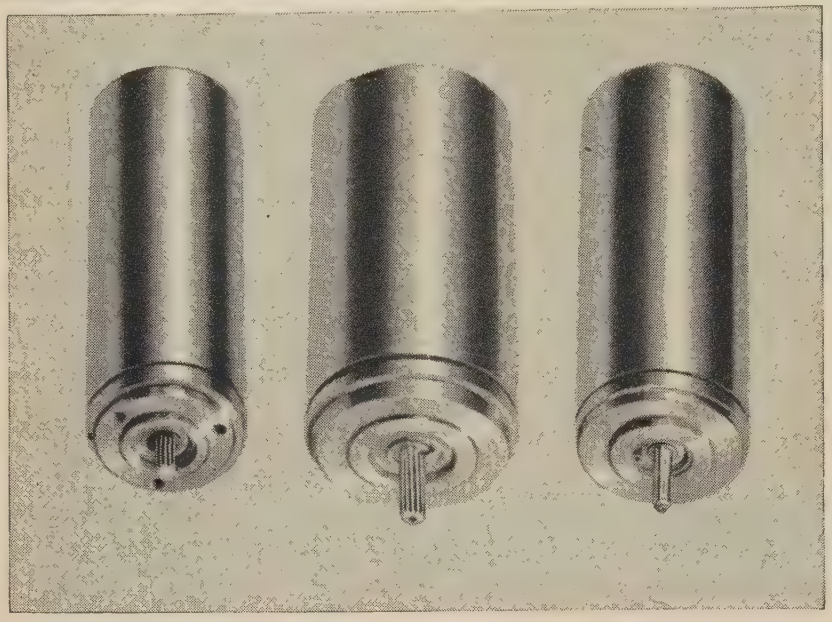

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Hypothetical Search Radars

	L-Band	S-Band
Scan rate (rpm)	5	4
Pulse rate (pps)	300	360
Azimuthal beamwidth (deg)	1.6	1.0
Pulse length (usec)	2	1.5
Noise figure (db)	8	9
Antenna gain (db)	33	36
Frequency (mc)	1200 (25 cm)	3160 (9.5 cm)
Peak power (mw)	1	2
Hits per scan	16	15

$$(9) \qquad R_n^4 = \frac{P_t G_T^2 \lambda^2 \sigma}{(4\pi)^3 V \overline{NF} k T B}.$$

Now you can derive the theoretical maximum range of your radar.

However, the accuracy of this calculation depends on how well the parameters of the equation are known or achieved in practice; for example, the values for σ or V used in the calculation may be in error. If the experimental value of R_n is well known, therefore, it is better to use that value rather than the theoretical range.*

In applying our formulas to conical-scan tracking radars, remember that the target is not in the middle of the beam. If the jammer is installed on the target, the relative gain of the radar antenna for the jamming signal therefore should be taken as about —½ db.

For three-dimensional radars, you may have to take collapsing losses into account. The proper method for this calculation must be found specifically for each radar. Collapsing and various other losses and gains can be taken into account by adding them to, or subtracting them from, the radar antenna gain.

If noise-jamming is compared with clipped AM noise, FM noise, etc., the "equivalent thermal noise" values should be found and the difference (in decibels) should be added to, or subtracted from, the jammer antenna gain. This value does not have to be accurate if radars are compared under identical jamming conditions.

Our formulas assume that the jammer's polarization is the same as the radar's and that the radar

* See W. M. Hall, "Prediction of Pulse Radar Performance;" Proc. IRE, Feb. '56, for many of the factors to be considered in determining the theoretical maximum range of a pulse radar.

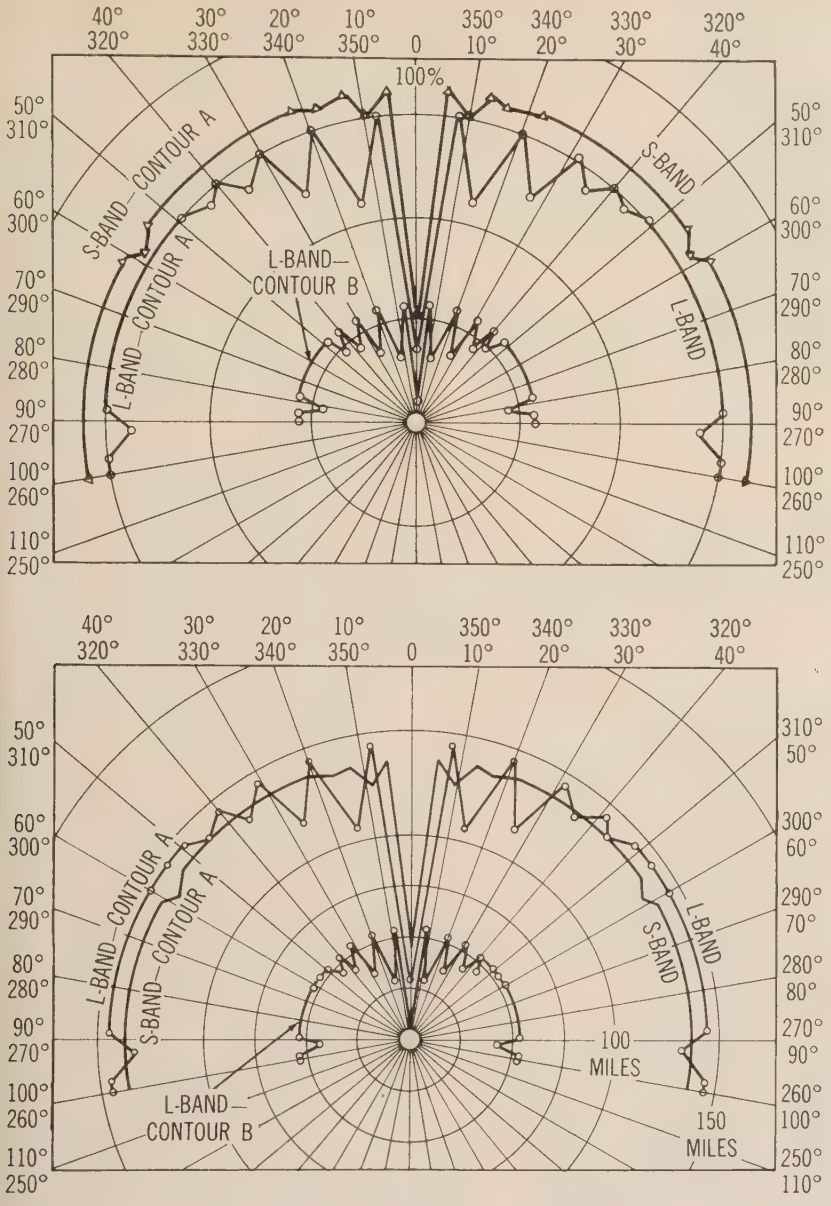

FIGURE 3: Contour maps of susceptibility as a percentage of normal range (top) and of range under jamming (bottom). The latter is found by multiplying the percentages of normal range by the normal range. Contours A are for a 100-mW jammer that is 100 miles from the radar; contours B, for a five watt jammer that is 50 miles from the radar. The jammer gain is six decibels in all cases.

rejects perfectly any image-jamming spectrum. For barrage-jamming, you must consider the possibility of imperfect rejection, which might affect the accuracy of the results. If the jammer is circularly polarized, three decibels should be subtracted from its antenna gain.

The cause-and-effect relationships in our formulas are not immediately obvious. For example, the formulas seem to show that the performance of the radar is improved—i.e., "percentage of normal range" ($R_j/R_n \times 100$) *is increased*—if the receiver noise figure is increased or the antenna gain is decreased. You get this impression because "percentage of normal range" implies a *comparison with normal performance.* Clearly anything tending to degrade the normal performance *by comparison* improves the performance under jamming. In the extreme case, in which the antenna has zero gain, the radar cannot be jammed—but neither can it detect targets.

In interpreting the results of our computations, you must also con-

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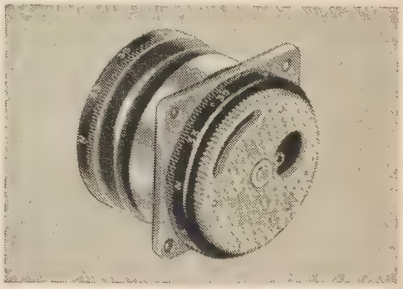
Efficient compensating device for servo system error.



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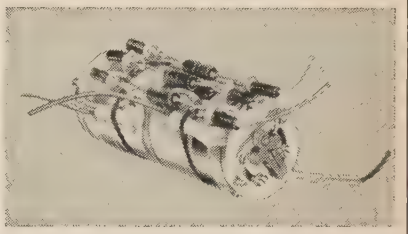

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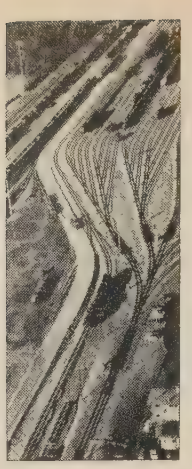
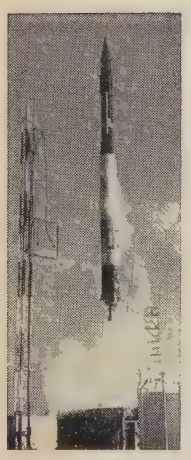


What's a big railroad supplier know about the little relays in a missile?



For 75 years, we've been building tough, reliable railroad signal equipment. Our signal relays are built to stand the rock-and-roll of high-speed trains.

We have relays that have been sitting out in the boon-docks in sub-zero and desert-hot temperatures for more than thirty years—getting only the standard two-year check up. Even after three decades, they're still making and breaking a circuit three times every second of every day.

With this experience, it was natural for us to start building miniature relays for the newborn missile age. We figured the missile people wanted a *reliable* relay. We also figured that the wee parts would make us bug-eyed. But our designers created a 6 PDT miniature relay with just three major assemblies . . . instead of a fistful of small parts.

It's a clean-looking relay. It has a minimum number of movable parts. But, a balanced rotary-type armature is its top feature. It rotates on an axis which passes through the center of gravity of the relay. This enables the relay to effectively resist applied linear acceleration forces from shock and vibration.

Our people build a reliable miniature relay. They know it, and they're proud of it. We're sure you will agree. Contact us for information.

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sider that the "normal range" of a radar against a given target is always measured with the gain set for the optimum receiver noise level. As the radar scans, the jamming noise level will rise and fall as the radar's sidelobes sweep over the jammer. A "naive" radar will not adjust the gain to optimize the noise level on each sweep. Therefore the "percentage of normal range" predicted by the equations may be optimistic. The predicted value is to be understood as a *maximum* that will be approached if the radar is provided with sufficiently "astute" anti-saturation, like IAGC, FAGC, and DBB detector-balanced bias).

Our formulas are useful primarily for radars whose range is determined entirely by a signal-to-noise ratio. The range of a tracking radar is a more complicated phenomenon, since there may be one range at which tracking errors exceed tolerable limits, another at which range tracking is broken, and so on. Furthermore, range in itself is not a universal criterion of effectiveness. If a tracking radar can be operated as a direction finder, it can use the jamming to shorten the *reacquisition time* after track is broken.

For search radars, a somewhat similar phenomenon occurs: the jamming itself gives the approximate azimuth of the jammer. "Range" should be interpreted as "the range at which the target pip is visible in the jamming."

The approach we have outlined does not give a go-no-go answer in a field situation, in which the probability of detection is a statistical question and depends on many factors. However, our approach does give a good "ballpark" estimate of the effects of noise on radar performance, particularly when two radars are being compared.

A hypothetical example shows how our formulas can be used to solve practical problems. Assume two radars with the characteristics given in the *Table*. The ranges of these two radars for a 2.5-m^2 target are about 160 miles for the L-band set and 140 miles for the S-band set.

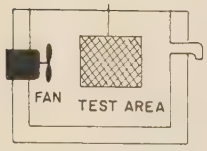
Assuming a jammer antenna gain of six decibels and a jammer is carried by the target, we can use *Equation 5* to plot a susceptibility graph for the two radars (*Fig. 1*). This graph shows, for any given

more on page 206

here's 4 ways CARDOX® CO_2

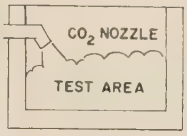
can help you achieve versatile...fast...low cost BELOW 0° F. ENVIRONMENTAL TESTING

1 dry ice chamber



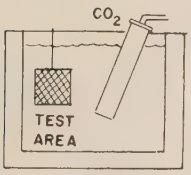
Simple, easy, inexpensive. A fan blowing over a wire basket full of crushed dry ice will reduce chamber temperatures from 0 to —70°F. A quick, low cost method for making occasional or isolated cold tests.

2 direct discharge of liquid CO_2



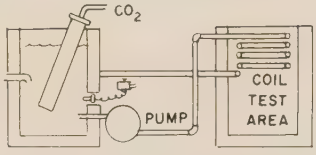
Easiest, most efficient method for consistent, cold testing in production operations. Bulk liquid carbon dioxide is discharged directly into the test chamber. You get controlled test conditions from 0 to —100°F. in 60 seconds or less. Best of all, one CO_2 storage tank can serve a battery of test chambers.

3 immersion tank method



For low cost production-line cold testing. Crushed dry ice or bulk liquid CO_2 is injected into an acetone, methanol or trichlorethylene base solution. Items to be tested are immersed in the slurry which has a temperature of minus 109°F. An ideal method of making cold "shock" tests.

4 indirect cooling method



Bulk liquid CO_2 is discharged directly into refrigerant line or surge tank containing acetone, methanol or trichlorethylene type solution. Refrigerant is then pumped thru test chamber to reduce temperature by means of coil-type heat exchanger. Major advantage—no CO_2 atmosphere in test chamber . . . an important factor where this condition is not desirable.

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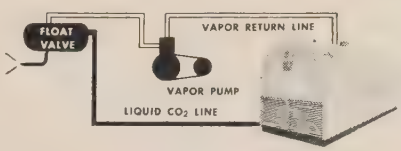
CARDOX® PATENTED RE-CYCLING SYSTEM keeps Liquid CO_2 COLDER . . . minimizes vapor loss

Low pressure liquid Carbon Dioxide storage tanks are located some distance from the point of use. Heat in the piping may vaporize a part of the liquid CO_2 so that vapor as well as liquid CO_2 arrives at the nozzle. This is undesirable for several reasons.

1. The vapor has reduced refrigerating effect and results in a loss of CO_2.
2. The vapor causes intermittent discharge; discharge rate and control is affected.
3. Starting may be delayed as large amounts of vapor must be discharged before pipe cools sufficiently to eliminate creation of vapor.
4. Vapor discharge can interfere with temperature control accuracy.



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Float valve just prior to the nozzle separates vapor from the liquid CO_2. A vapor pump connected to a return line pumps the vapor back to the storage tanks.

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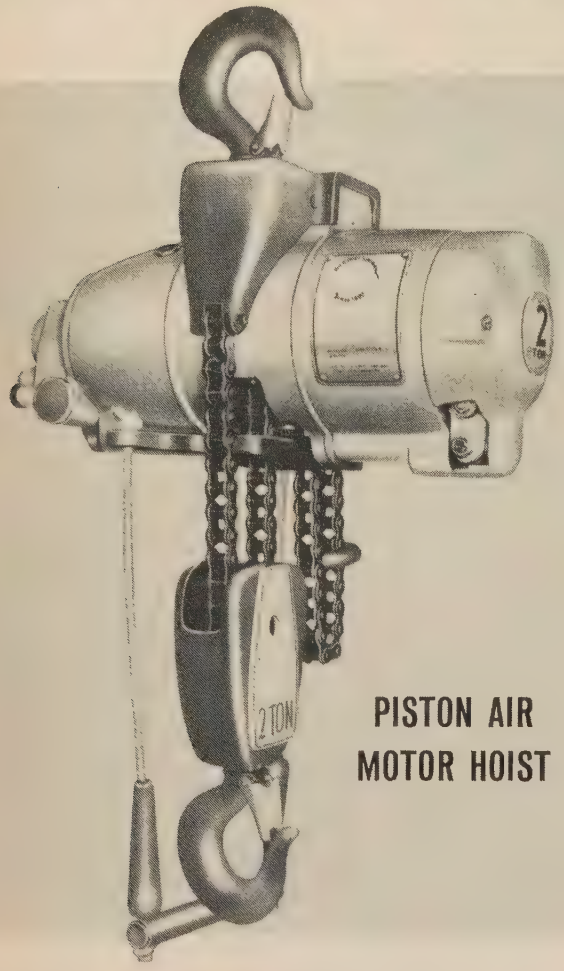

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86-2V20	2000	19	78
86-2V40	4000	10	100

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MODEL	CAPACITY	SPEED	WEIGHT
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Electronic warfare bibliography

The unclassified books and documents listed in this bibliography are available at the USAF Air University Library, Maxwell AFB, Ala. This library also has available a collection of unclassified periodical articles dealing with electronic warfare that could not be listed here because of space limitations.

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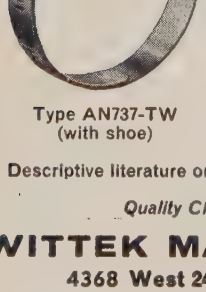

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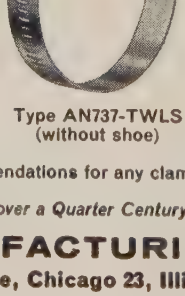

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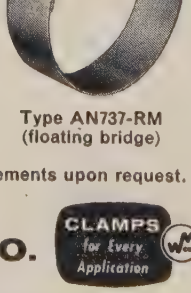

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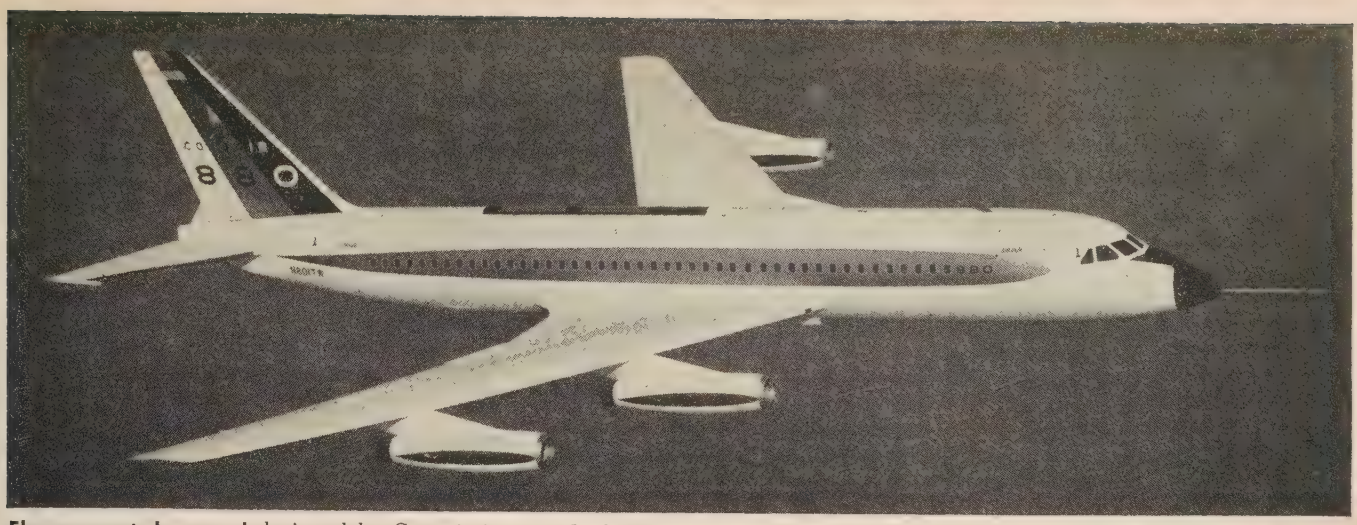

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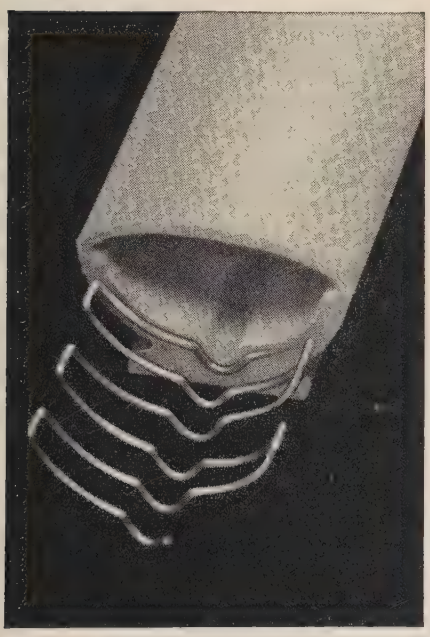

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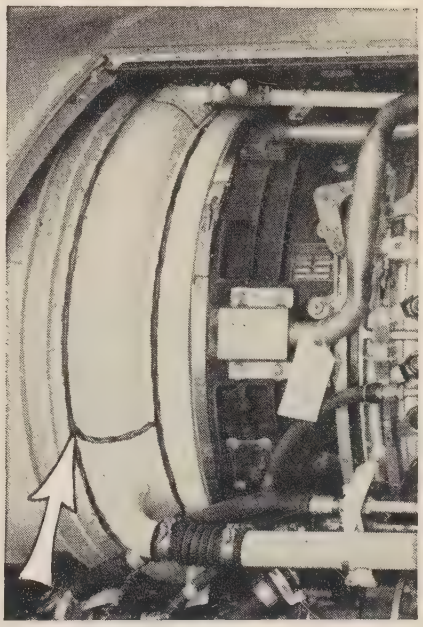

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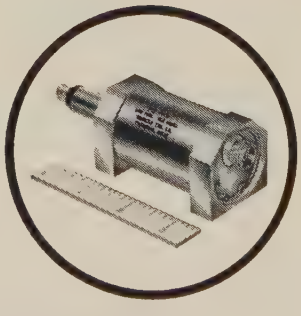
Operating range	475 to 550 psi (others available)
Output voltage	0 v to 5 v dc (28 v dc input)
Accuracy: Linearity & Hysteresis	Better than 0.15% of reading
Temperature effects (0 to 165 F)	Better than 0.5% of reading
Vibration	30 g, 0 to 2000 cps



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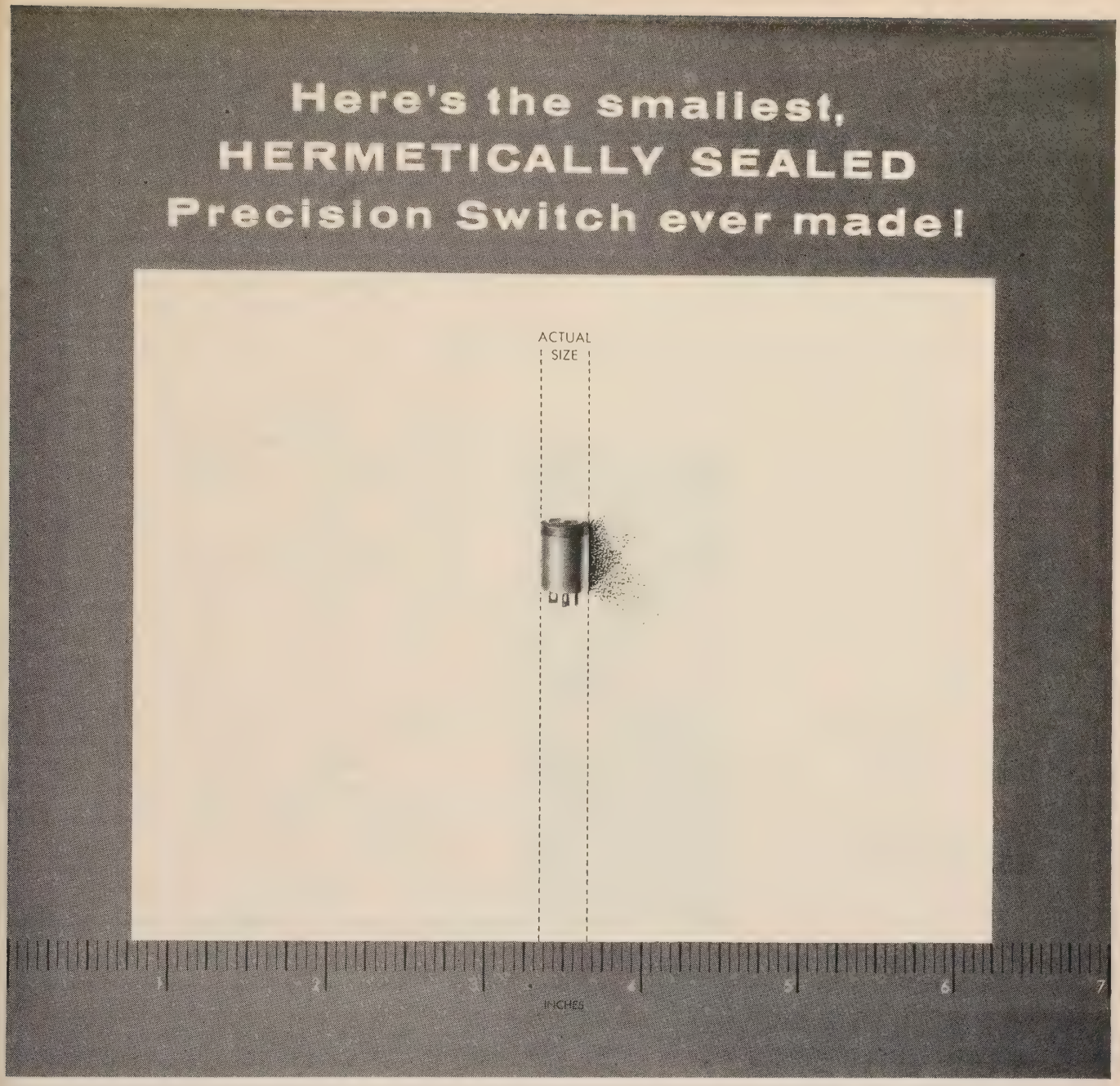
continued from page 200

jamming power, the distance at which a jammer-carrying airplane can fly toward the radar without being accurately located. Note that the curve for the S-band radar in the susceptibility graph is displaced six decibels to the right from the L-band curve. The S-band radar can be said to be six decibels less susceptible to noise jamming.

From the susceptibility graph, you can construct curves for range under jamming vs jamming power per megacycle (*Fig. 1*). These curves show that, although the L-band set has the greater no-jamming range, the S-band radar's range will be greater if there is even slight jamming (one mw/mc).

You can also construct jamming maps for the two radars to show their susceptibility to jamming and performance under jamming. Assume the antenna patterns for the two radars are as shown in *Figure 2*. Using *Equation 4* (for a jammer not carried by the target), you can then construct maps that show where 2.5-m² targets can be detected by the radars in the face of jamming (*Fig. 3*).—End

Here's the smallest, HERMETICALLY SEALED Precision Switch ever made!



KLIXON TYPE AT1-1

Here is the first truly subminiature, precision calibrated switch that is *hermetically-sealed* to MIL-S-8484B. Prior to sealing, the AT1-1 is especially processed and filled with a dry, inert gas to insure reliability for "Dry Circuit" applications. The exterior parts are corrosion resistant. The solder type terminals, brought out through fused glass seals, are tin dipped to facilitate soldering.

This new "KLIXON" switch is designed around a unique, "W" shape, snap-acting element to meet stringent shock and vibration requirements. Where switch reliability, space and weight-saving are important, this switch sets new standards of compactness and represents the latest advances in the "state of the art."

Here is the answer to a designer's prayer for the smallest, lightest, snap-acting, environmental free switch that can be made and yet still be a reliable, precision device. Write for further detail on various means of mounting and actuators.

SPECIFICATIONS

of KLIXON Type AT1-1

Actuating force	12 ± 8 ozs.
Release force	1 oz. minum.
Pretravel	.005" approx.
Overtravel	.003" min.
Movement differential	.002" approx.
Minimum life cycles	10,000
Weight	.036 ozs.
Amb. temp. range	65°F to 275°F
Current capacity	3 amps. 28VDC resistive
Contact separation	.010" approx.
Vibration resistance	40 G's
Shock resistance	100 G's

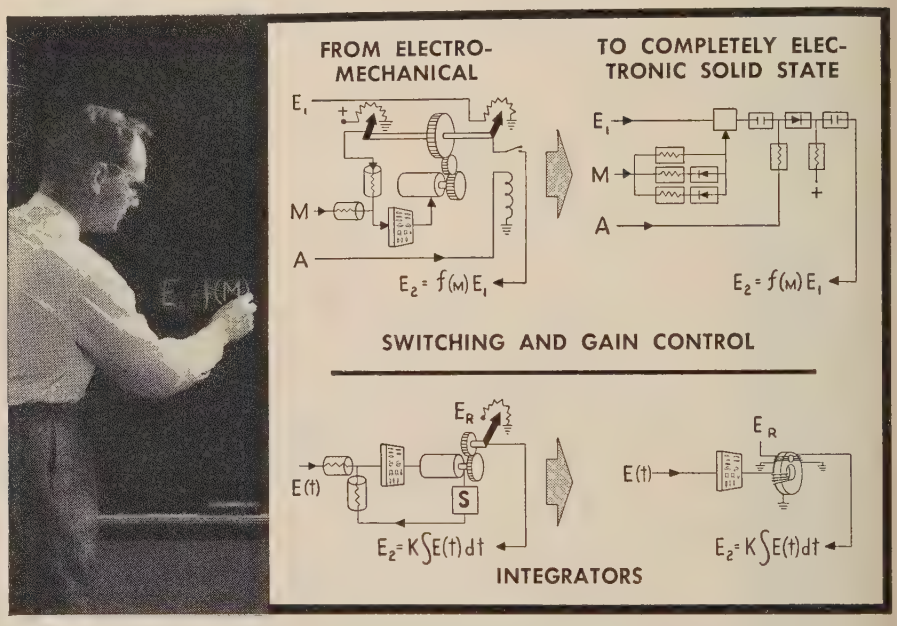
TEXAS INSTRUMENTS
INCORPORATED
METALS & CONTROLS DIVISION
3705 FOREST STREET • ATTLEBORO, MASS.

Spencer Products: Klixon® Inherent Overheat Motor Protectors • Motor Starting Relays • Thermostats • Precision Switches • Circuit Breakers

Write in No. 133 on Reader Service Card at start of Product Preview Section

TECHNICAL KNOWLEDGE + EXPERIENCED MANAGEMENT + SPECIALIZED CRAFTSMANSHIP = **KNOWMANSHIP**

Knowmanship scoring breakthroughs in solid-state electronics



One of the chief assets an associate contractor can offer is his ability to advance "the state of the art." This capability is part and parcel of Eclipse-Pioneer KNOWMANSHIP.

Take automatic flight control systems. In 1954, E-P flew the first successful, fully-transistorized system —forerunner of models now flying or ordered for 34 different airlines of the world, as well as the air forces and navies of the United States and Canada. Currently—on the crest of new E-P breakthroughs in solid-state electronic circuitry—we are developing an automatic flight control system *with no moving parts* between the input sensors and output servos. Effect of eliminating conventional rotating shafts, gear trains, cams, motors, relays, etc., from a typical system will be to *halve* flight control system size, weight, power consumption, and cost. *At the same time, operational reliability will be increased.* The new solid-state systems will be particularly well suited to operation with the new generation of airborne digital computing systems.

If you seek advanced "state of the art" thinking and capability for *your* contracting team, E-P KNOWMANSHIP could well be the answer. To find out, call, wire, or write us today.

69% of E-P's procurement dollars go to small business.

ECLIPSE-PIONEER
TETERBORO, N. J.
DIVISION of
Bendix
AVIATION CORPORATION

AUTOMATIC FLIGHT CONTROL • CENTRAL AIR DATA SYSTEMS • SPECIALIZED INSTRUMENTATION • NAVIGATION COMPUTERS AND DIRECTORS
STABLE PLATFORMS • INERTIAL GUIDANCE • RADAR ANTENNA STABILIZATION AND TRACKING SYSTEMS • GROUND SUPPORT EQUIPMENT

Write in No. 134 on Reader Service Card at start of Product Preview Section

AEROSPACE electronics took the limelight at this year's IRE Convention in New York City despite an almost crushing defeat at the show's beginning. The IRE planners, in an unusual burst of "originality," decided that the opening curtains of the show would be parted by an impulse from Pioneer V, at the time over a million miles away. The signals from space came in loud and clear. But the prime mover of the curtains, a small electric motor that was to be energized on command from the satellite's signals, suffered from a very earthly malfunction—a blown fuse. As a last resort, man (who, we've always suspected, is hidden behind the curtains in such situations) had to draw the strings, to the embarrassment of all.

A NUMBER of excellent aerospace electronics papers, presented at the show's technical sessions, commanded by far the most attendance. Interestingly enough, Litton Industries ran a small-scale technical program of its own at a nearby hotel in competition with the regular sessions. Litton engineers presented six papers on aerospace subjects, all of high quality. Attendance was by invitation only and comparatively low.

Litton may well have started a trend for future shows—instead of the liquid refreshment of the hospitality suite, you offer the engineers at the show a diet of good technical information.

HIGH ALTITUDE antenna power handling capabilities were discussed in a report given to the IRE by Stanford Research Institute engineers Scharfman and Morila. They noted that, when a vehicle passes through the ionosphere, the loss mechanism of an antenna changes from free to ambipolar diffusion. As a result, they claimed, the power handling capability of the antenna is considerably reduced.

The SRI engineers noted that, if the antenna dimensions are scaled inversely with frequency and directly with pressure, the breakdown power will remain fixed for different frequencies. To increase power handling capabilities, they suggested dc biasing, changes in antenna configuration, and radomes.

RESULTS of a reliability program on the AN/ASB-4 bombing-navigation system for the Boeing B-52 were revealed by R. D. Kuehn, of IBM's Military Products Div. As designed by IBM, this system has five standard amplifier types that make up 54 per cent of all the electronic units. The reliability design concentrated on conservation operation of electron tubes and components and on packaging to withstand the environment.

As a result of its program, IBM increased the mean time to failure of the equipment sevenfold from prototype life test to field use in SAC aircraft. IBM estimates that, through corrective action after the prototype life tests, its program prevented the failure of 2500 amplifiers. The net saving to USAF, based only on actual depot repair costs, was $375,000.

DESPITE the reliability efforts, a serious intermittent relay problem appeared in the system after several hundred hours of airborne operation. IBM traced it to relays that made and interrupted little or no current. The problem was solved by the development of a sealed-coil relay with precious-metal contacts.

KAISER INDUSTRIES gave the "first authorized description" of its method of generating a contact analog display for instrument flight in a paper by Balding and Susskind. The display presents "an integrated picture of all the information that the pilot needs to fly the aircraft without reference to conventional instruments." The information is presented much as it would be in the real world—for example, any increases in altitude show up as a contraction of ground texture; an increase in speed results in a speed-up of the apparent motion of the ground.

Triangular wave generators, Kaiser revealed, are the basic circuits used to generate the complex analog signals. The generators or their follow-up circuits are operated upon, gated, sampled, and otherwise modified in accordance with external signals derived directly from the aircraft sensors or via a central computer.

FLYWHEEL control of space vehicles has been studied in a two-phase program by Martin and was discussed in a paper by Vaeth. The first phase of the study involved a single-axis hand analysis to optimize the controller transfer function for various response rates. The second phase culminated in a three-axis analog computer study that analyzed the gyroscopic cross-coupling ramifications and evaluated the effects of parametric variations.

Martin's conclusions were:

- Flywheel controllers can be used for effective attitude control of space vehicles.
- The added complexity of compensating for gyroscopically induced torques isn't justified by the dynamic-accuracy improvement it produces.
- The major problem areas are system reliability and flywheel saturation.
- One solution lies in the careful use of differential gravity (dumb-bell effect) for satellite vehicles.

COSMIC rays and radiations from the sun, the stars, and interstellar space were studied by The Franklin Institute with a view to their possible use in space navigation. In a paper reporting on their work, Franklin researchers Franklin and Birx said that cosmic rays were discounted early in the study, mainly because no discrete sources of radiation are available and no discrete line spectra exist. It was found that Doppler shift—and therefore the velocity of space vehicles — could be measured only with the hydrogen 21-cm line. No other suitable lines in the RF range have yet been discovered.

Natural radiation in the optical range holds the greatest promise for space navigation, the paper concluded, noting that many excellent detectors are available in this range. However, low signal levels are the major problem.

The sphere represents perfection in many ways to the designer of inertial instruments. It can be decoupled completely from torques due to external magnetic, electric, and gravitational fields. It has perfect symmetry, can be formed to extreme accuracy by simple machine processes. It is the primary element of Honeywell's electrically suspended gyro.

professional opportunities at Honeywell Aero

INERTIAL SYSTEM DEVELOPMENT

Systems Analyst—employs mathematical techniques such as operational calculus, matrix algebra, and difference equations to the solution of problems concerning performance characteristics of various system configurations including analysis for error introduced by sensors and computer, requirements for alignment, and optimization of the system configuration.

Digital System and Logic Designer—requires familiarity with capabilities of various digital computer configurations and ability to employ system and logic relations in specifying necessary configuration for solving inertial navigation problem.

Electronic and Mechanical Designers—engineers with background in transistor circuitry, inertial sensor development and evaluation, and precision mechanical equipment design are needed to perform component development and evaluation, and to design mounting and alignment equipment.

APPLIED RESEARCH

Programmer Analyst—mathematician with experience in the use of medium and large scale digital computers for analysis of scientific problems.

Human Factors Engineer—capable of analysis and direction of experiments in human motor skills, and application to man-machine systems involving automatic control techniques.

Systems Analyst—capable of conducting research studies involving new techniques of space navigation and guidance.

DESIGN AND DEVELOPMENT

Flight Control Systems—analytical, systems, and component engineers to work in areas such as advanced flight reference and guidance systems. Positions range from analyzing stability and control problems, systems engineering—through design, testing, and proof of electrical and mechanical equipment—including flight test and production test.

Advanced Gyro Design—Engineers with two and up to twenty years' experience in precision gyro and accelerometer development, servo techniques, digital techniques, solid state electronic development, advanced instrumentation and magnetic component design.

Electronic Circuit Designers—experienced in the areas of analog/digital computers, transistor circuits, servos, instrumentation, and/or gyro stabilization.

For the less experienced professional engineer, there are opportunities in the Evaluation Laboratory which lead to careers in any of the above fields.

To investigate any of the above professional opportunities, please write in confidence to Bruce Wood, Dept. 611A, Honeywell Aeronautical Division, 1433 Stinson Blvd. N.E., Minneapolis 13, Minnesota.

To explore professional opportunities in other Honeywell operations coast to coast, send your application to H. K. Eckstrom, Honeywell, Minneapolis 8, Minnesota.

Honeywell

H Military Products Group

Check Employment Inquiry Form on Page 211

space/aeronautics

CONFIDENTIAL

May 1960
(good until 7/15/60)

Employment Inquiry Form

(Not an application for employment)

THIS INQUIRY FORM is a service that makes it easier for the interested reader to explore employment opportunities with organizations featuring recruitments advertising **in this issue.**

To use this Form, follow these simple steps:

(1) Tear out this page.

(2) Check off the organization(s) listed below whose employment offers are of interest to you. **Use typewriter or pencil.**

(3) Turn to the back page of this Form and answer the questions on it.

(4) Mail this form (in a stamped envelope) to:

Reader-Service Dept.
SPACE/AERONAUTICS
205 East 42nd St.
New York 17, N.Y.

We will do the rest and promptly forward a copy of your Inquiry Form to each of the organizations you have checked. Depending on their specific personnel requirements they will get in touch with you at your home.

I am interested in the employment opportunities at:

- ☐ AiResearch Mfg. Co. 218
- ☐ Avco Corporation; Crosley Div. 220
- ☐ Bell Aircraft Corp. 109
- ☐ Convair; Astronautics Engrg. Div. 182
- ☐ Garrett Corp. 218
- ☐ General Electric Co. Heavy Military Electronics Dept. 213, 214
- ☐ Light Military Electronics Dept. 219
- ☐ Missile & Space Vehicle Dept. 132
- ☐ Guided Missiles Range Div.; PanAm Airways, Inc. 334
- ☐ Jack & Heintz, Inc. 218
- ☐ Lockheed Aircraft Corp. California Div. 277
- ☐ Missiles & Space Div. 230, 231
- ☐ Magnavox Procurement Div. 221
- ☐ Martin Co.; Denver Div. 113
- ☐ Minneapolis-Honeywell Regulator Co.; Aero Div. 210, 216
- ☐ Nat'l. Aeronautics & Space Administration 292
- ☐ Pan American Airways, Inc.; Guided Missiles Range Div. 334
- ☐ Raytheon Mfg. Co. 215
- ☐ Republic Aviation Corp. 220
- ☐ Research Labs.; United Aircraft Corp. 116
- ☐ Rohr Aircraft Corp. 216
- ☐ System Development Corp. 217
- ☐ Texas Instruments 189
- ☐ Westinghouse Electric Corp.; Baltimore Div. 222

OTHER (Some organizations' recruitment advertising in this issue may have arrived too late for inclusion in the above list. If you are interested in the employment offers of any of these organizations, just note its name and the page number of its advertisement in this space. Please refer only to ads keyed to this form.) :_____

_____

_____

NOTE: If you have an immediate interest in any special employment opportunity advertised in this issue and would like to give more details about your qualification than can be noted on this Form, we advise you to send your resume directly to the person or department given in the advertisement. We'd appreciate it if you'd mention SPACE/AERONAUTICS in your application.

space/aeronautics

CONFIDENTIAL

May 1960
(good until 7/15/60)

Employment Inquiry Form

Please type or print (with pencil)

(NOT an application for employment)

FIELDS OF INTEREST (in order of importance, note the general fields in which you would like to work—e.g., basic research, dynamics, structures, rocket propulsion, electronic systems, pneumatics, testing, materials, production, ground support, etc.): _____

SPECIALIZED JOB EXPERIENCE (describe the specific technical areas in which you have worked —e.g., flutter, fatigue, fuel systems, circuit miniaturization, servo systems, hydraulic pumps, tool engineering, orbit mechanics, telemetry, data processing, wind tunnel testing, etc.): _____

JOBS AND EDUCATION

List your last 3 employers:

EMPLOYER	CITY & STATE	YEARS EMPLOYED	JOB TITLE OR FUNCTION

List your college and university degrees:

SCHOOL	YEARS ATTENDED	DEGREE

Special Training _____

PERSONAL DATA

AGE ..... U. S. CITIZEN ☐ YES ☐ NO If not, when do you expect to become a citizen? .....

Name: .....

Home Address: .....

Home Telephone: .....

Make sure you have checked the companies you are interested in on the other side of this Form. Then put the Form in a stamped envelope and mail it to Space/Aeronautics.

Check Employment Inquiry Form Page 211 ➡

Professional placement report
for Electronics Engineers

How the continuous need to improve the nation's space surveillance capabilities opens avenues for new engineering careers

The continuous need we are talking about at General Electric refers to the fact that future-generation missiles, satellites and deep space probes will require refined or entirely new detection techniques, including many that have not yet been conceived.

For example, it is anticipated that for every technical discipline now utilized in the detection field, at least one more must be found to apply within the next 10-year period.

With this in mind, General Electric is increasing its electronics engineering staff now working on advanced missile, satellite and deep-space-probe detection systems. Keeping pace with this expansion, the Company added a new building last year, and another will be ready for occupancy in a few months.

First clues to this trend were obvious in General Electric's well known "Golfball Study," published five years ago. This study compared the problem of missile detection to that of locating a golfball 200 miles away, using the most advanced techniques available in 1954. The problem no longer has such proportions, thanks to the creative imagination of dedicated General Electric engineering, scientific, and technical personnel responsible for designing and developing the unique surveillance sub-system of the Ballistic Missiles Early Warning System (BMEWS) which is receiving headline attention today.

Find out more about these creative and self-expressive opportunities now open to qualified personnel in one of the most vital technologies of the space age.

GENERAL ELECTRIC

Immediate openings for qualified electronics engineers

RADAR EQUIPMENT SYSTEMS SPECIALISTS capable of conceiving and directing the design of long-range radar systems. Desirable experience includes 3 to 10 years in at least one of the following: radar systems design, antenna systems, RF components, transmitters, radar receiver systems or radar data processing systems. Salary structure is fully equal to the professional requirements of the job.

ADVANCED SYSTEMS ENGINEERS capable of defining future defense and space detection problems including deep space-probe tracking. Also the ability to conceive and establish the feasibility of optimum systems solutions to these problems—making use of the most advanced techniques and understandings. Also required is an ability to recognize the need for, and coordinate the development of, new techniques and the exploration of new phenomena. Experience requirements include a Bachelor degree plus a combination of advanced training and several years' experience in both the theoretical and practical aspects of detection systems engineering. A desire to work in the conceptual phase of systems design with the analytical ability required to evaluate and demonstrate the effectiveness of the proposed systems is essential.

FIELD OPERATIONS ENGINEERS for systems management teams to be deployed at complex radar systems installations of the BMEWS type. Systems-oriented Electronics Engineers are needed who have the ability to assume responsibility for installation, checkout, and integration of major radar systems. Background in high-powered Klystron transmitters, low-noise receivers and digital data processing equipment is desirable. A Bachelor degree is required.

ADDRESS YOUR INQUIRY IN CONFIDENCE TO:
MR. JOSEPH WOOL, PROFESSIONAL PLACEMENT, DEPT. T-2
MISSILE DETECTION SYSTEMS SECTION
HEAVY MILITARY ELECTRONICS DEPARTMENT
GENERAL ELECTRIC COMPANY
COURT STREET, SYRACUSE, NEW YORK

Qualified applicants will be invited to visit us in Syracuse at Company expense. Relocation assistance will be provided. 177-25

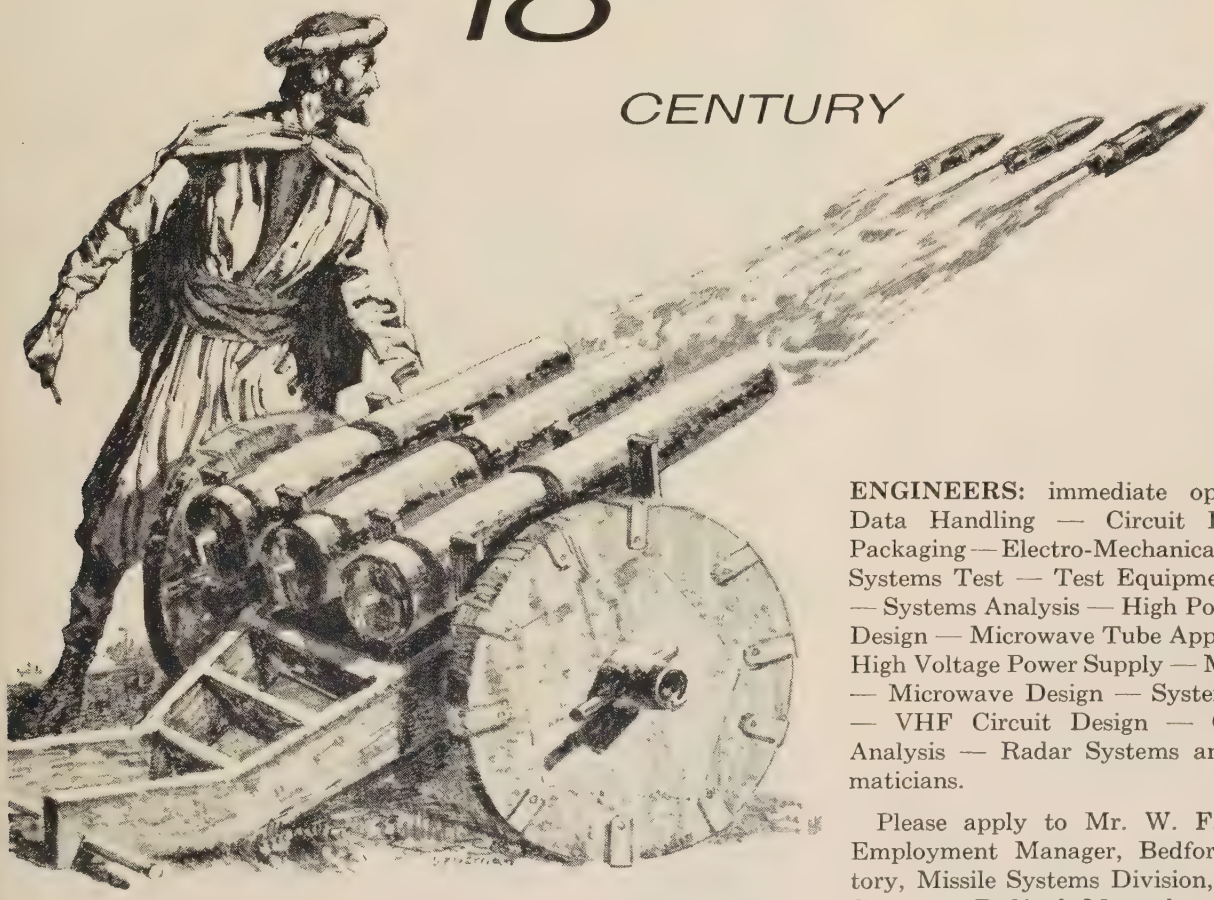
GENERAL ELECTRIC

ROCKET CORPS 18th CENTURY

In 1760, Indian Prince Tepper Sahib trained a 5,000-man rocket corps. Using rocket launchers of the type illustrated the Sahib repelled a British attack against his walled city — and started the defeated British thinking about rockets of their own!

Missiles have become greatly more sophisticated since the Sahib first broke the British Square. As a vital part of one of the world's largest purely electronic companies, Raytheon Missile Systems Division is making great advances in this field. The exciting new Pin Cushion Project for the selective radar systems missile identification and the continually being improved Navy's air-to-air SPARROW III and Army's HAWK, are examples of their outstanding creative work.

We are now seeking talented, qualified people to maintain Raytheon's leadership in this constantly advancing field. Raytheon's Missile Systems Division creates a climate for such talent — perhaps *your* talent.



ENGINEERS: immediate openings in Data Handling — Circuit Design — Packaging — Electro-Mechanical Design — Systems Test — Test Equipment Design — Systems Analysis — High Power Radar Design — Microwave Tube Application — High Voltage Power Supply — Modulators — Microwave Design — Systems Design — VHF Circuit Design — Operations Analysis — Radar Systems and Mathematicians.

Please apply to Mr. W. F. O'Melia, Employment Manager, Bedford Laboratory, Missile Systems Division, Raytheon Company, Bedford, Massachusetts.

15B

RAYTHEON MISSILE SYSTEMS DIVISION

... creates a climate for talent.

Check Employment Inquiry Form on Page 211

INERTIAL SYSTEMS DEVELOPMENT

. . . . . there are opportunities at Honeywell Aero for the engineer or scientist who is interested in participating in this growing field of technology. While specific inertial systems experience is desirable, you may also be qualified by your background and/or related experience for activities in the inertial systems development at this time. Specific openings include:

SYSTEMS ANALYST

Mathematician or engineer with strong background in vector analysis, operational calculus, matrix algebra and related techniques. To carry out analysis of inertial systems configurations including error evaluation.

DIGITAL SYSTEMS AND LOGIC DESIGNER

Familiar with digital logic techniques at current state of the art; capable of organizing computing systems to perform various tasks including logical design and critical parameter specification.

ELECTRONIC ENGINEER

Electrical engineering degree plus experience in miniaturized semiconductor electronics development. To design servo, pickoff, and other electronics for use with gyros and accelerometers.

ENGINEERING PHYSICIST

Physicist with practical and theoretical understanding of mechanics, magnetism and electricity to analyze and develop inertial sensors of novel and original design.

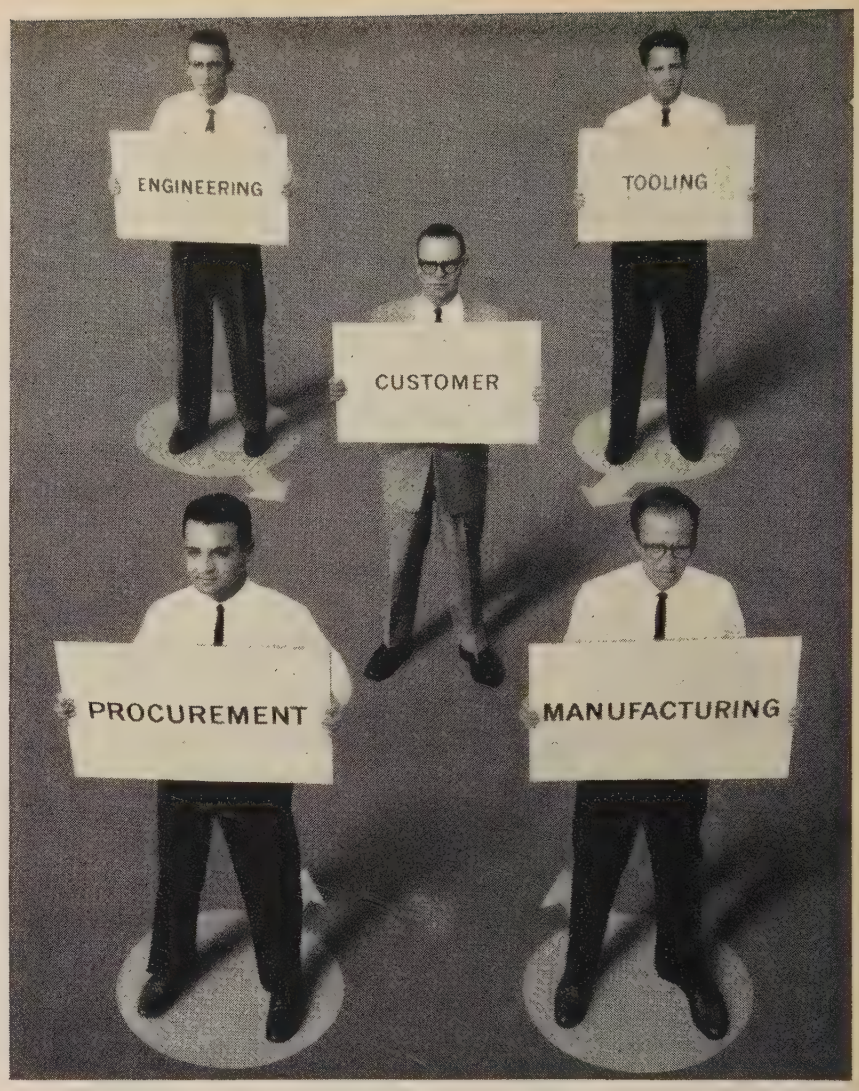
To discuss these or other openings, write Mr. R. O. Maze, Chief Engineer, Marine Systems Group, Dept. 611B, Aeronautical Division, 1433 Stinson Blvd., Minneapolis 13, Minn.

Honeywell

Military Products Group

To explore professional opportunities in other Honeywell operations coast to coast, send your application in confidence to H. K. Eckstrom, Honeywell, Minneapolis 8, Minnesota.

Check Employment Inquiry Form on Page 211



INTEGRATION OF EFFORT *

Complete integration of every effort – engineering, tooling, procurement and manufacturing – has been a guiding philosophy at Rohr since the company was founded. As a result, Rohr offers a uniquely satisfying atmosphere to people who join the company.

Regardless of assignment – whether engineering, tooling, or production – you follow the complete program as the unified efforts of all departments are brought to bear on the solution to a problem. It is a creative, shirt-sleeve atmosphere, with wide-open channels of communication and action.

To Rohr's people it means greater freedom to work with ideas and to see those ideas translated into better methods, better techniques, better materials.

To Rohr's customers, it means better products, at less cost, in shorter time. The confidence of those customers is reflected in a secure backlog approaching a quarter billion dollars, more than half in commercial contracts.

Integration of effort, progressive management, product diversification, distinguished associates, fine living conditions – these are among the many reasons that Rohr is the company known by the people it keeps!

Rohr invites inquiries from men who can contribute to the company's leadership in the aerospace industry. Write to Mr. J. L. Hobel, Industrial Relations Manager, Rohr Aircraft Corporation, P.O. Box 878-H, Chula Vista, California.

ROHR
AIRCRAFT CORPORATION

WORLD'S LARGEST PRODUCER OF COMPONENTS FOR FLIGHT
Chula Vista & Riverside, Calif.

***Another reason ROHR is a company known by the PEOPLE it keeps!**

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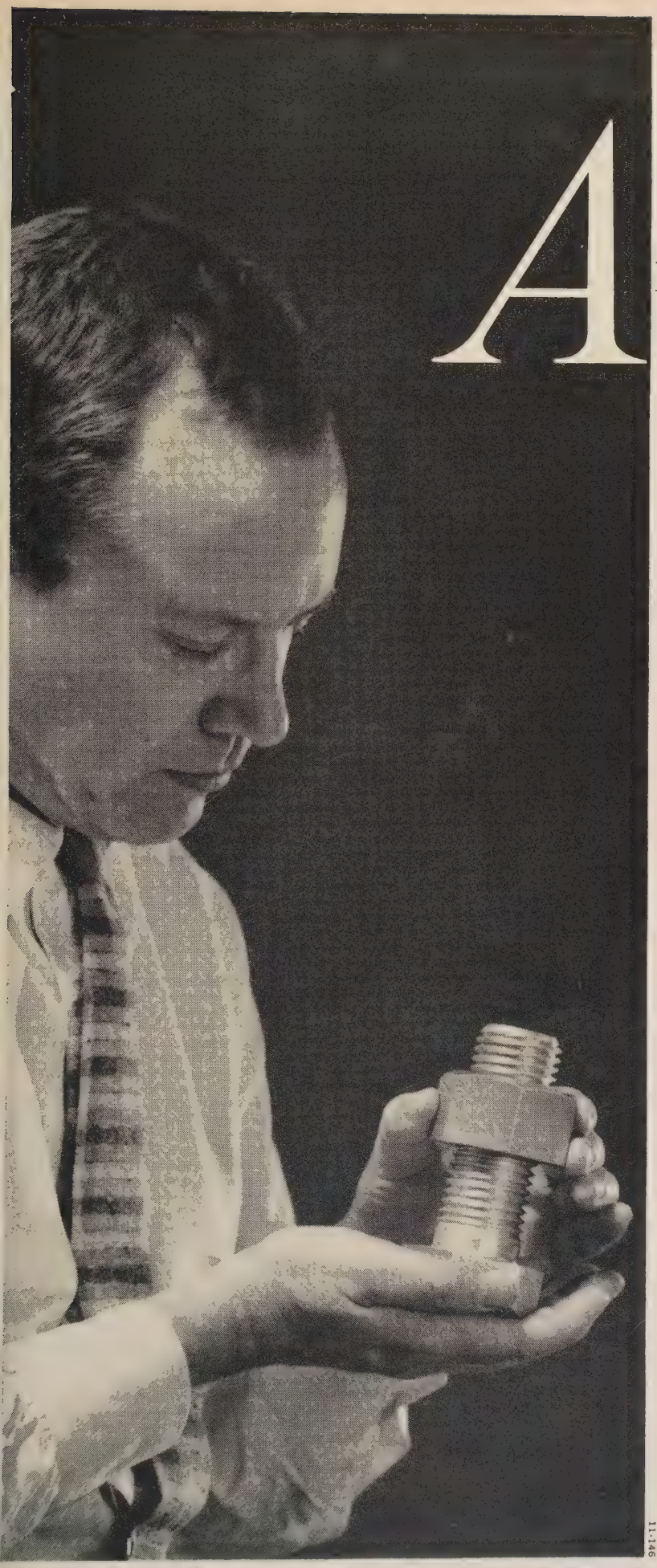

Analytical Engineers:

Are your skills being used in truly advanced work?

Are you satisfied with the way your native abilities, training and experience are being utilized? Is the scope broad enough for you? Must you constantly tread the same territory, or can you plunge into the woods to pit your skills against new challenges?

If you are not interested in exploring new technological terrain, you will not be interested in System Development Corporation. For our work is concerned with the development of extremely large control systems in which the relationships of men and machines pose entirely new problems for analytical engineers.

At the present time we have key openings for engineers with proved analytical ability in the areas of communications, computers and associated equipment, simulation, information theory, weapons system analysis. Please send your inquiry to Mr. E. A. Shaw, SDC, 2424 Colorado Avenue, Santa Monica, California.

"A Mathematical Model of an Air Defense Operation and a Method of Evaluation," a paper by SDC's staff, is available upon request. Please address inquiries to Mr. E. A. Shaw at SDC.

SDC

SYSTEM DEVELOPMENT CORPORATION

Santa Monica, California • Lodi, New Jersey

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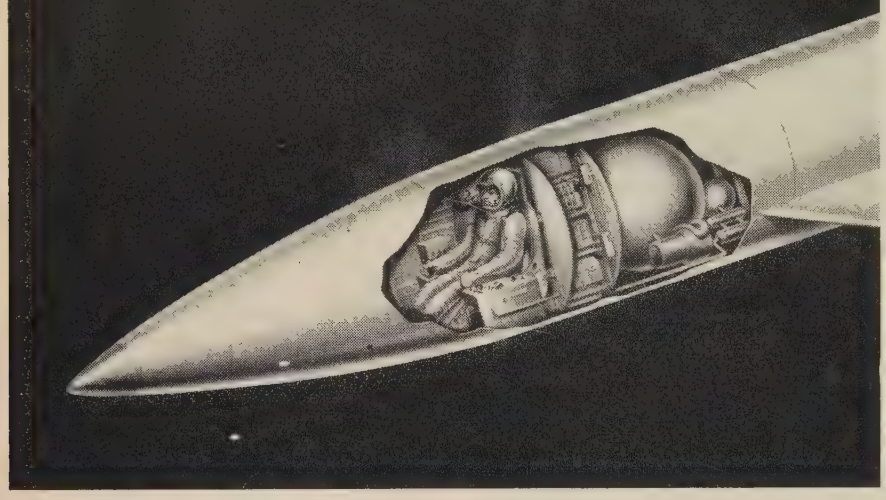
THERE IS NO CEILING ON IDEAS



• *Advanced hydrogen systems being developed by The Garrett Corporation solve the problem of keeping men alive and equipment operating for long periods of time in future satellites and space capsules.*

Engineers at The Garrett Corporation's AiResearch Manufacturing Divisions are dealing with challenging problems in fast-moving fields.

Diversification of effort and vigorous leadership have made Garrett the world's largest manufacturer of aircraft components and systems and a leader in specialized missile and spacecraft systems.

Excellent positions are available for qualified men with M.S., Ph.D. and Sc.D. degrees for work in these areas:

- Environmental Control Systems—Pioneer, leading developer and supplier of air conditioning and pressurization systems for commercial and military aircraft, and life support systems for satellites and space vehicles.
- Aircraft Flight and Electronic Systems—Largest supplier of airborne centralized flight data systems; also working with other electronic controls and instruments including missile and submarine applications.
- Missile Systems—Largest supplier of accessory power units, AiResearch is also working with hydraulic, hot gas and hydrogen systems for missiles, liquid and gas cryogenic valves and controls for ground support.
- Gas Turbine Engines—World's largest producer of small gas turbine engines, with more than 9000 delivered in the 30-850 hp class. Studies include industrial and nuclear applications.

Immediate openings exist for
MANUFACTURING ENGINEERS

to work with product design engineers on all aspects of production including forming, machining, assembly, material processing, operating standards and manufacturing feasibility of products in the above fields.

Send resume to: ***Mr. Robert Richardson***

THE GARRETT CORPORATION
AiResearch Manufacturing Divisions
Los Angeles 45, California • Phoenix, Arizona

Check Employment Inquiry Form on Page 211

If POWER appeals to you

. . . You'll like it here . . . because power is our business. POWER CONVERSION, CONTROL, FREQUENCY CHANGING, REGULATION, ADVANCED ELECRICAL SYSTEMS

We need:

Solid-State Electronics

EE with experience in electronic circuit design for advanced work on conversion and control equipment using solid-state devices and magnetic amplifiers.

Electric Power Systems—Research

PhD electrical for power systems analysis and power conversion development.

MSEE with experience feedback controls, analog computation and systems simulation.

ME experience high-speed, high-temperature electrical machinery design for space power plant research.

Heat Transfer & Vibration

ME or MS in math—for analytical work in thermodynamics and heat transfer.

ME with knowledge of instrumentation for shock and vibration test.

Exciting future in new product development with Jack & Heintz, an aggressive leader in the aero-space field.

Wonderful working conditions. Jack & Heintz is big enough to have the most modern facilities and lab equipment, yet small enough to avoid bureaucracy.

Relaxed suburban living. We're located in a beautiful Cleveland residential area. University facilities are close at hand, if you'd like to take advantage of our company-supported educational program.

Send detailed confidential resume to:

Mr. C. E. FORBES,
Manager of Technical Employment

JACK & HEINTZ, Inc.
SYSTEMS FOR GROUND SUPPORT, MISSILES, AIRCRAFT
17600 Broadway Avenue • Cleveland 1, Ohio

✻ For an example of J&H development work, see our advertisement in this issue.

Check Employment Inquiry Form on Page 211

NGINEERS:

A NEW CONCEPT IN PROFESSIONAL JOB SELECTION

New technical tests enable you to calculate your probability for success at LMED – in 1 hour at your own home!

BY GENERAL ELECTRIC'S LIGHT MILITARY ELECTRONICS DEPARTMENT

If you've been thinking of changing your job some day—or in the near future—but have hesitated because of the many uncertainties involved, Light Military's new concept in professional job selection will be of paramount interest to you.

What is it?

The new concept is based on a series of technical tests developed and pretested by Light Military engineers. They are designed to be taken, scored and evaluated by the individual engineer, all in the privacy of his own home. And, because the sole purpose is to provide you with a novel, objective means for self-appraisal, your score need not be divulged to us at any time.

Here's how it works:

First, fill out the coupon below and check off the tests which apply to your training and professional experience. Forward the completed coupon to us and in a few days you will receive the tests, a sealed answer sheet and explanatory material.

During a convenient hour at home, take the test and score it with the answer sheet provided. Then, compare your performance with the criterion group composed of Light Military engineers at all levels who took the same test. In most cases you will be able to relate your score to years of experience, from 2 to more than 10.

What it measures:

If your adjusted score is equal to, or more than the years of experience you possess, the probability is excellent that a significant community of technical interest exists between you and The Light Military Department. In addition, a valid assumption can be made that a high probability for success awaits you here. And remember, your score need not be divulged to us at any time; it is for your own guidance exclusively!

CURRENT AREAS OF ACTIVITY AT THE LIGHT MILITARY DEPT.

SPACE COMMUNICATIONS & TELEMETRY • MISSILE & SATELLITE COMPUTERS • SPACE VEHICLE GUIDANCE • UNDERSEA WARFARE SYSTEMS • THERMOPLASTIC DATA STORAGE • SPACE DETECTION & SURVEILLANCE • COMMAND GUIDANCE & INSTRUMENTATION • INFRARED MISSILE APPLICATIONS

Facts about the tests

1. Each technical test is composed of 40 multiple choice questions.
2. To find answers for some questions, mathematics is involved—but only to the degree normally associated with the work.
3. The "mix" of questions includes some easy ones, some bordering on the state of the art.
4. None of our engineers achieved a perfect score.
5. The test for Engineering Administration is psychological, designed to reveal aptitudes and abilities most often found in good engineering managers or administrators.

MAIL THIS COUPON FOR YOUR TESTS

Mr. R. Bach
Light Military Electronics Dept.
General Electric Company, French Road, Utica, New York

Please send me tests (limited to 2 subjects per individual) answer and self-evaluation sheets covering the areas checked:

☐ RADAR ☐ MICROWAVE ☐ ELECTRONIC PACKAGING (ME)
☐ COMMUNICATIONS ☐ ADMINISTRATIVE ENGINEERING

NAME _____

HOME ADDRESS _____ HOME PHONE _____

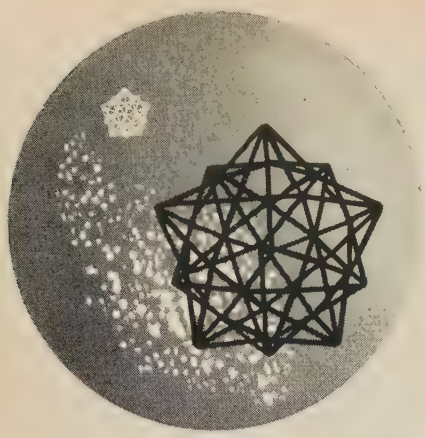
CITY _____ ZONE ____ STATE _____

DEGREE(S) _____ YEAR(S) RECEIVED _____

60-ME

LMED
LIGHT MILITARY ELECTRONICS DEPARTMENT

GENERAL ELECTRIC



ENGINEERS
SCIENTISTS

FUTURISM in contemporary R&D

Radical departures from traditional forms of scientific investigation are the keynote of Republic Aviation's forward-looking programs in space exploration and upper atmosphere flight. In an environment that regards with skepticism the seeming validity of conventional conclusions, engineers and scientists seek below-the-surface solutions of problems... bypassing the superficial.

Expanding the scope and depth of present programs is Republic's recently completed $14 million Research and Development Center. Extensive facilities here are an invitation to professional men to realize the future by solving today's most perplexing problems.

• • • • • • • • • • • • • • • • • • •

SENIOR LEVEL OPENINGS EXIST IN THESE IMPORTANT AREAS:

Space Electronics *(Guidance, Navigation, Communications)* / Hypersonics / Hydromagnetics / Nuclear Power Packages / Advanced Computer Technology / Applied Mathematics / Space Environmental Studies *(Life Science)* / Celestial Mechanics / Electronic Theory / Plasma Physics / Radiation Studies / Re-entry Techniques / Fluid Mechanics / Materials Research & Development

Please forward resumes to:
Mr. George R. Hickman
Technical Employment Manager,
Department 61E

REPUBLIC AVIATION

Farmingdale
Long Island, New York

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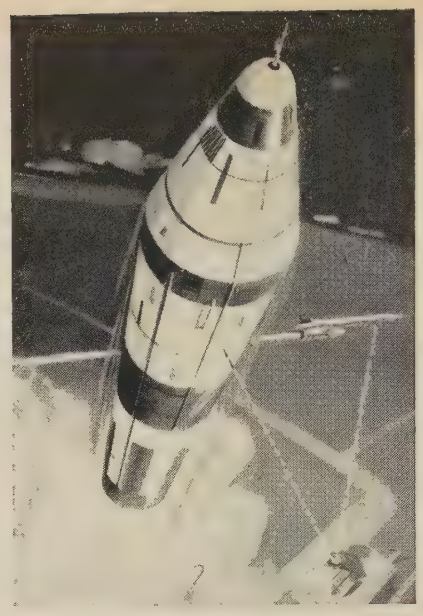

Opportunities for...
communications specialists

Avco/Crosley is looking for qualified individuals to share in the development of new and exciting concepts in communications. At Crosley, a wide range of communications projects offers challenging opportunities to experienced personnel.

Research and Development activity extends from Range Safety Receivers for missiles to Meteor-Trail Scatter Systems for reliable long-distance radio links, and includes advanced concepts in tactical communications for mobile units.

Openings exist in the following areas:

- Radio Receivers and Transmitters
- Miniaturized Circuits
- Transistors
- Digital Circuitry
- D. C. Amplifiers
- Low-Noise Amplifiers

Accelerated research into the development of Radar Systems has also created unusual positions in this fast growing field. Specific areas of interest include:

- Microwave Techniques
- Circuit Design and Development
- Solid State Building Blocks
- Pulse and Video Circuitry

For more information, write to Mr. P. B. Olney, Manager of Scientific and Administrative Personnel, Dept. C-50, Crosley Division, Avco Corporation, 1329 Arlington Street, Cincinnati 25, Ohio.

Avco / Crosley

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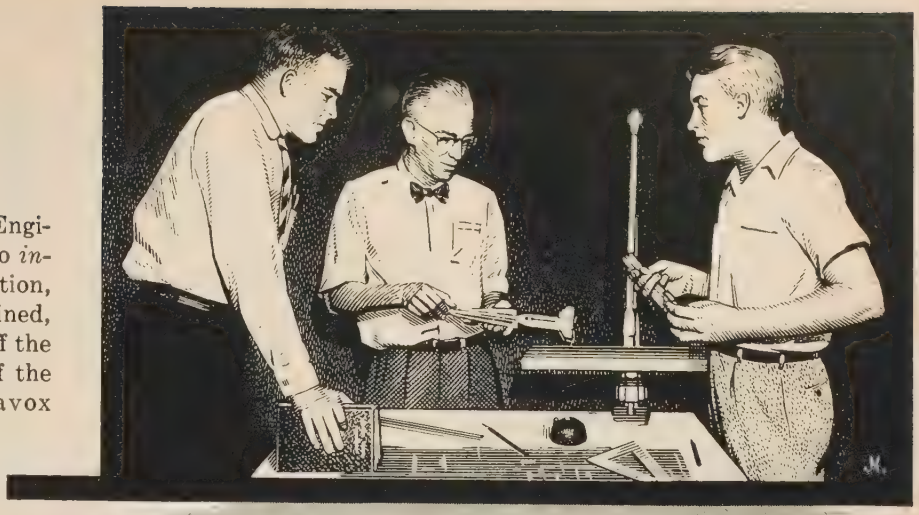
ATTENTION ALL ENGINEERS

If you are seeking new job opportunities be sure to read all employment advertisements in this issue — both in this Special Section and throughout the magazine

Men

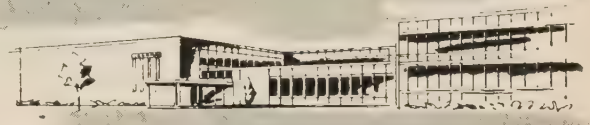
who refuse to get lost in the crowd. Engineers with a yen for challenge . . . who *intend* to see their ideas put into motion, These are the special breed of determined, creative, thinking individuals who staff the government and industrial division of the Magnavox Company. And Magnavox needs more people like them . . .



To

fill present openings at the three Magnavox military and industrial plants. In Fort Wayne, Indiana, where families enjoy the good life of a growing Mid-Western community. In Urbana, Illinois, home of the University of Illinois which has one of the largest communications, physics and radar research centers. Or in America's largest electronic community, Los Angeles, California.

FORT WAYNE, INDIANA



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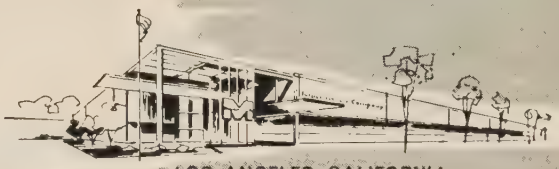
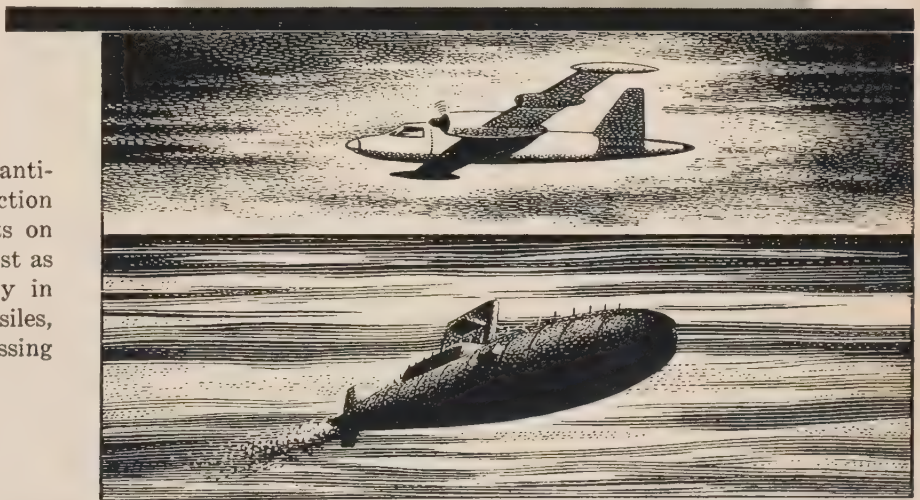


LOS ANGELES, CALIFORNIA

Do

engineering to develop advanced anti-submarine warfare systems in conjunction with the Navy Department. Projects on tap for the future offer experiences just as challenging and rewarding—not only in ASW, but in Communications, Missiles, Airborne Radar and Data Processing Equipment as well.



Phone Dick Eary (collect, of course) at Eastbrook 9721 in Fort Wayne or write him for complete information.

Magnavox

COMMUNICATIONS | RADAR | DATA HANDLING | ASW | MISSILES

THE MAGNAVOX CO. • DEPT. 233 • *Government and Industrial Division* • FORT WAYNE, IND.

Check Employment Inquiry Form on Page 211

Why don't you Talk with Westinghouse

. . . about their Microwave Program?

Westinghouse-Baltimore offers exciting career opportunities for engineers to participate in the development of Microwave systems. Talk with Westinghouse and get all of the facts on projects, facilities, opportunities for advancement, and be sure to ask about the pleasant living in the Chesapeake Bay area . . . a sportsman's paradise.

CURRENT OPENINGS

Microwave Theory
Underwater Acoustics
Microwave Antennas & Components
Microwave Transmitters & Receivers
Molecular Electronics
Systems Planning
Field Installation & Test

Send resume to: Mr. A. M. Johnston, Dept. 290

Westinghouse

BALTIMORE

P.O. BOX 746 Baltimore 3, Maryland

AIR ARM • ELECTRONICS • ORDNANCE

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product index to advertising

THIS IS A SPECIAL REFERENCE to the product information given in the advertisements in this issue. It is intended solely to help the reader make the best use of these ads. Therefore the index does not necessarily cover all the products made by each advertiser. Also, definitions and cross-listings are not intended to exhaustively describe each product but merely to make sure that each product can be found with reasonable ease by the reader looking for it.

Similar indexes to services and employment opportunities featured in ads follow this index.

Advertisements for which complete proofs were not available to the Editorial Department by the closing date are not necessarily covered by these indexes. (Proofs can be forwarded internally by the Production Department only for advertisements meeting the closing dates.)

For more detailed information on any product or service advertised in this issue or featured in its Product and Data Reviews, use the handy Reader Service Card.

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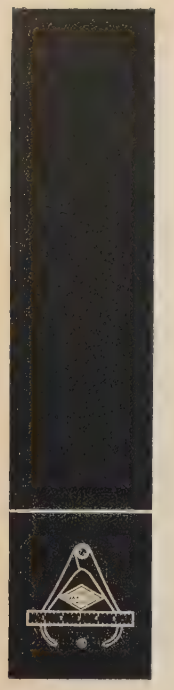


ANNOUNCING A NEW CORPORATE NAME

for The Garlock Packing Company

Garlock Inc. becomes the new name for The Garlock Packing Company, Palmyra, N. Y., to reflect more accurately its broad diversification of products and markets.

Originally established to manufacture mechanical packings, Garlock now produces over 2,000 different styles of packings, gaskets, seals, molded and extruded rubber and plastic products for every major industry.

The new corporate name, Garlock Inc., more closely identifies this 73-year-old company with the growth and development of its product lines. *Today, industry goes to Garlock for such widely diversified products as:*

- Hydraulic-Pneumatic Packings
- Oil and Grease Seals
- Gasketing and Expansion Joints
- Braided Packings
- Molded and Extruded Rubber Parts
- Plastic Stock Shapes and Fabricated Parts
- Mechanical Seals for Rotating Shafts
- Metal Packings
- Leather Packings
- Electronic Components
- Dry Bearing Materials
- Fluorocarbon Tank Linings
- Missile and Rocket Components

To help you in selecting or applying these products, Garlock offers the services of over 126 thoroughly-trained sales engineers, 175 electronic component manufacturers' representatives, 180 authorized bearing distributors and 69 foreign distributors. Conveniently located warehouses and stocking points assure Garlock customers of prompt delivery.

At Garlock Inc., design and development of new or improved products and materials is an ever-present objective. To this end Garlock maintains extensive research and laboratory-test facilities. In addition, Garlock engineers and chemists are always ready to work with you in seeking solutions to tough application problems.

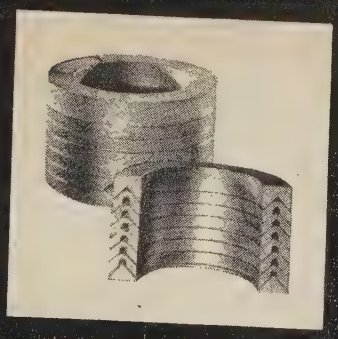
GARLOCK

To find out more about "the new Garlock," call the nearest of our 26 sales offices, or write to Garlock Inc., Palmyra, N. Y. *To assure prompt attention,* please refer to *Garlock Inc.* on all future correspondence and orders.

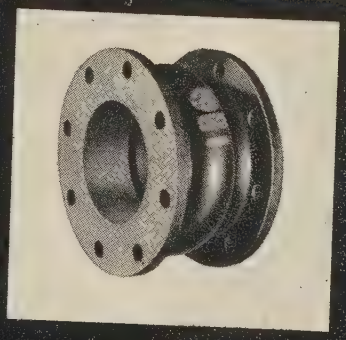
Canadian Div.: Garlock of Canada Ltd.

Order from the Garlock 2,000 . . . two thousand different styles of Packings, Gaskets, Seals, Molded and Extruded Rubber, Plastic Products.

Write in No. 135 on Reader Service Card at start of Product Preview Section

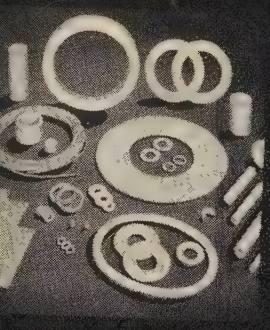


Hydraulic-Pneumatic Packings

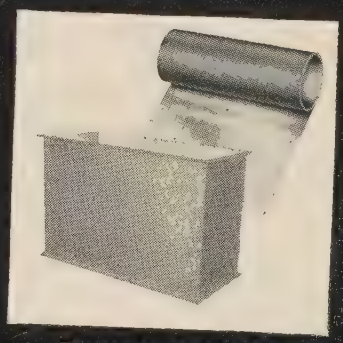


Expansion Joints

Molded and Extruded Rubber Parts



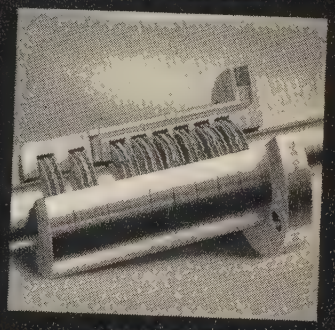
Plastic Stock Shapes
and Fabricated Parts



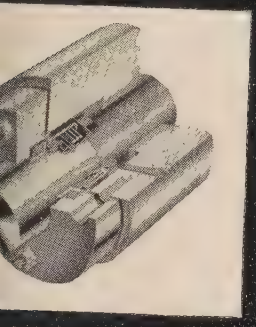
Fluorocarbon Tank Linings

Oil and Grease Seals

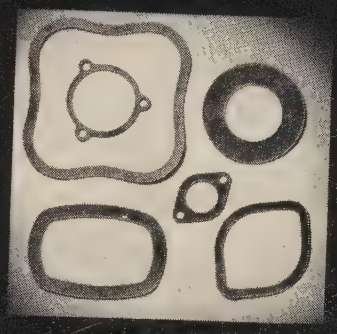
Braided Packings



Metal Packings

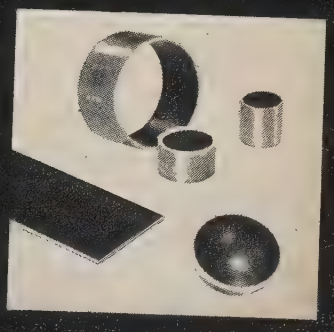


echanical Shaft Seals



Gasketing

Spiral Wound Gaskets



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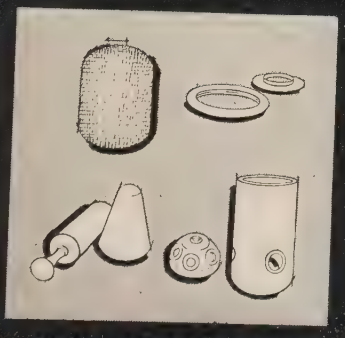
N C .



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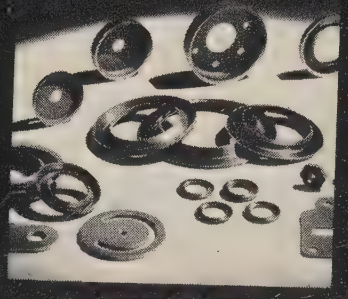
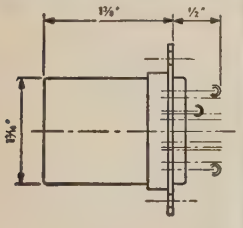


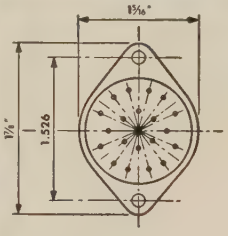
Leather Packings

Electronic Components

The First...

wedge action relay





NEW MARK II RELAY

Insures ULTRA-reliability under most extreme environmental and operating conditions.

Revolutionary new WEDGE ACTION supersedes and surpasses "Wiping Action."

Contact pressure constantly increases during over-travel.

- Temperature range: — 65°C to 200°C.
- Contact bounce: NONE.
  Operating vibration: 5 to 2,000 cps, 30 G's.
  Operating shock: 100 G.
- Contact rating: dry circuit to 2 amps.
- Extremely low contact resistance.

BRIEF DESCRIPTION: Six pole, double-throw, hermetically sealed. Meets and exceeds specifications MIL-R-5757C and MIL-R-25018.

PAT. NO. 2,866,046

Write for illustrated literature.

ELECTRO TEC CORP.

P. O. BOX 37K, SOUTH HACKENSACK, N. J. BLACKSBURG, VA., ORMOND BEACH, FLA.

SLIP RINGS • SWITCHES
RELAYS

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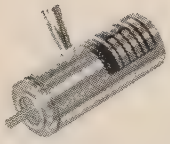
the science of

rotation...

SIZE 8—SERVO
TACHOMETER
TYPE SJ7HLZ7-4



High Performance
plus Low Tachometer Power

This small motor tachometer features high torque output per watt input and excellent signal to noise ratio. It is an ideal choice for those applications where space is limited yet the high performance and reliability of a precision damping, motor generator is required. Other BuOrd Size 8 motors, tachometers and gearhead units are available, built to E.A.D.'s high standards as well as to meet specific customer requirements.

TYPICAL CHARACTERISTICS

GENERAL: Frequency, 400 c.p.s. • Rotor Inertia, 1.2 gm.cm.² • Torque at Stall, 0.34 oz. in. • Oper. Temp. Range, −55° to 150° C • Weight, 2.8 oz.

MOTOR: Motor Voltage (fixed & control phases), 26 • Power (Stall), 2.5 Watts

GENERATOR: Excitation, 26v, 400 c.p.s. • Power (Stall), 1.5 Watts • Output at 0 RPM, 0.010 V.R.M.S. • Output Voltage, 250 Mv/1000 RPM • Signal to Null Ratio, 25/1 at 1000 RPM

Write for complete Technical Data

Eastern Air Devices' contribution to systems design is the science of rotation. This concept represents the basic engineering and production approach of a company whose products are specified everywhere to meet the critical performance and reliability requirements of today's systems . . . tomorrow's designs. Eastern Air Devices' product line — the most complete and diversified in the industry today — and the company's new developments in bearing life, high temperature insulations, oxidation protection . . . reflect the technical confidence developed during 18 years in the application of the many sciences of rotation. At Eastern Air Devices you are assured of a 1960 scientific approach to the application of rotating electrical components . . . whether you select from the standard line or order special designs.

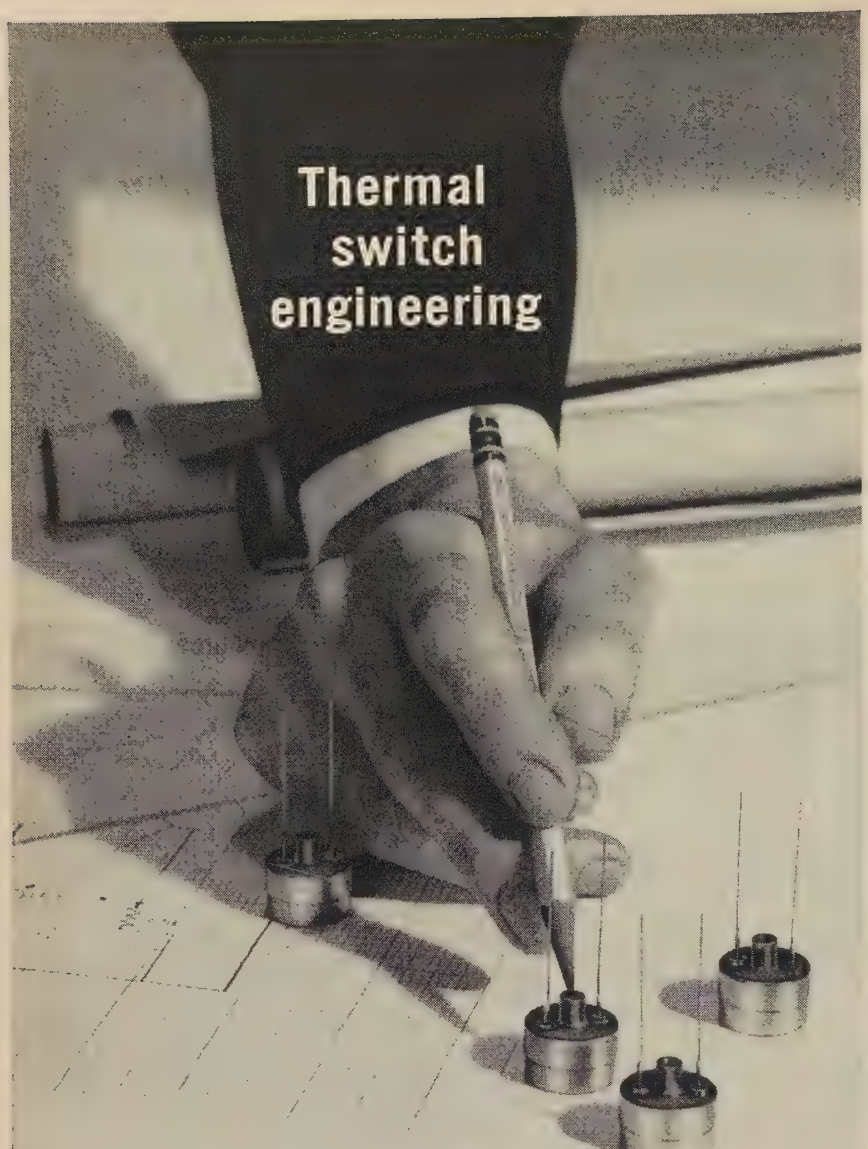
EAD

EASTERN AIR DEVICES, INC.

Subsidiary of Norbute Corporation • Dover, New Hampshire

INDUCTION MOTORS • SERVO MOTORS • HYSTERESIS MOTORS
INTEGRATING TACHOMETERS AND MOTOR TACHOMETERS • BLOWERS
INERTIALLY DAMPED SERVO MOTORS • TORQUE MOTORS • FANS
DAMPING MOTOR TACHOMETERS • GEAR MOTORS • ALTERNATORS

Write in No. 137 on Reader Service Card at start of Product Preview Section



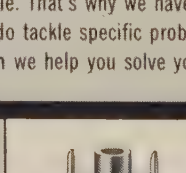
ANOTHER "CRITICAL" CONTROL SWITCH FROM CPI RESEARCH

If you are concerned with measurement of surface temperatures in aircraft and airborne electronic equipment in confined spaces, this may be a thermal switch you could use. We designed and manufactured it to meet exacting specifications of a prominent aircraft manufacturer.

Chances are your needs may require modifications or even a completely new switch. We have always realized that there are few "critical" control switches that can be all things to all people. That's why we have the research and development engineers who can and do tackle specific problems of thermal control. Can we help you solve yours?

This new hermetically sealed, bi-metal, single or 2-wire switch has calibration range of -20F to 600F; safe momentary overshoot to 800F; available with various type mountings. When inquiring, mention "button" switch.

CPI



CONTROL PRODUCTS, INC.

310 Sussex Street, Harrison, N.J.

Write in No. 138 on Reader Service Card at start of Product Preview Section

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AiResearch inboard GTP 70 gas turbine engine delivers electrical power to Air Force Boeing KC 135 Stratotanker while it's on the ground. DC control power for the turbine is delivered by the Chatham 28V20, a lightweight, fan-cooled, 20 amp selenium transformer rectifier featuring operation over a wide frequency range (320 to 522 cps).

CHATHAM T-R helps AiResearch "wake up" fuel-ferrying jet tanker

This is the AiResearch inboard gas turbine engine. It supplies the space age power which operates instruments, lights, radio, radar and cabin heaters on the Air Force Boeing KC 135 Stratotanker while it's on the ground.

AiResearch specifies the Chatham 28V20 AC to DC transformer rectifier to assist the turbine in the ground warm-up job that helps the tanker streak away with split-second efficiency on its refueling rendezvous with thirsty, far-from-home jets.

The Chatham 28V20 delivers DC power to the turbine generator for all control functions. The converter also supplies the power to recharge the turbine engine battery, which supplies the starting power for the AiResearch equipment.

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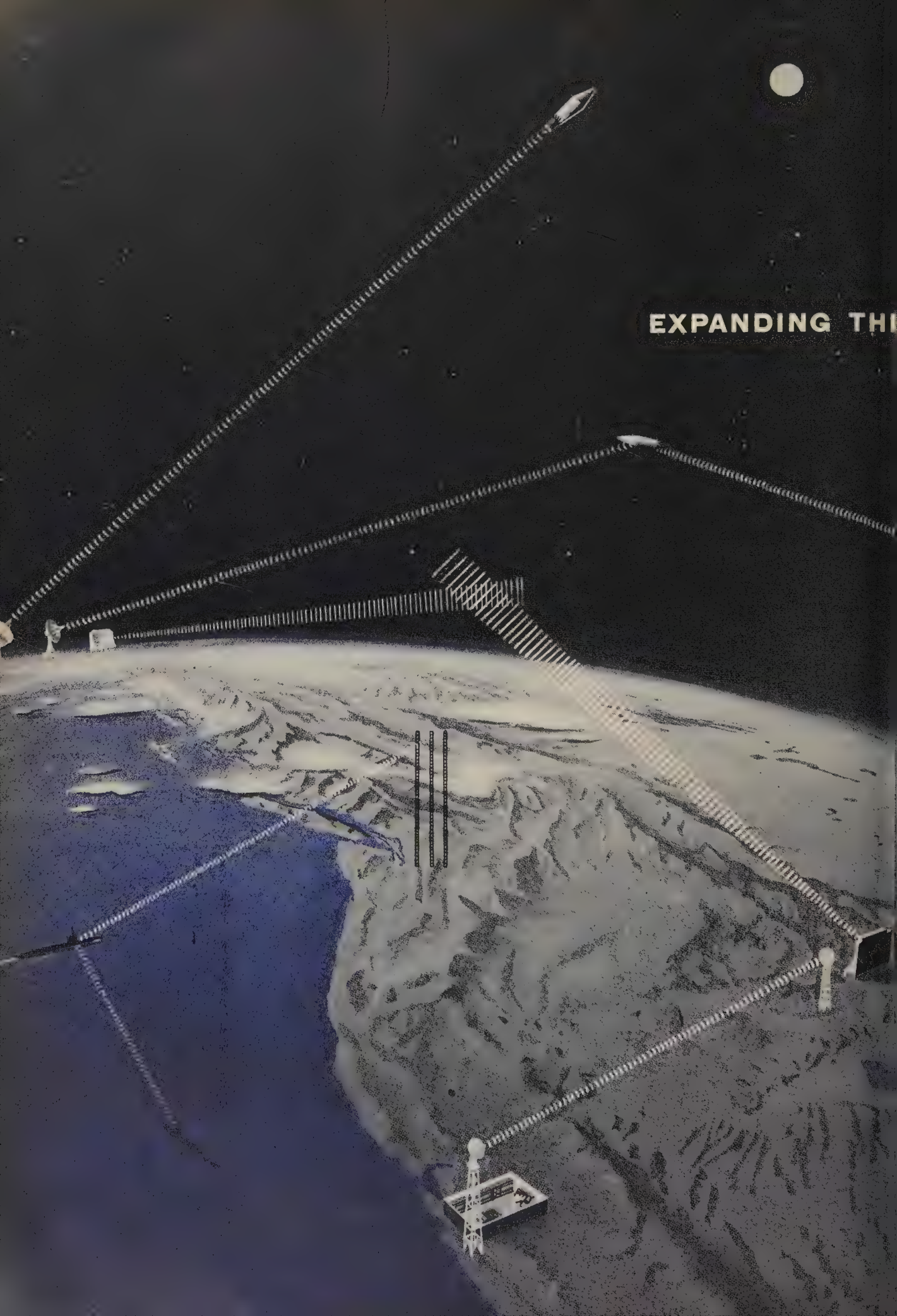
EXPANDING THI

Herodotus, the historian, records (490 B.C.) the use of burnished shields for military signaling. This was the forerunner of the heliograph, invented by Sir Henry C. Mance, which came into wide use centuries later.

ONTIERS OF SPACE TECHNOLOGY IN

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If you are experienced in work related to any of the above areas, you are invited to inquire into the interesting programs being conducted and planned at Lockheed. Write: Research and Development Staff, Dept. E-16, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense clearance required.

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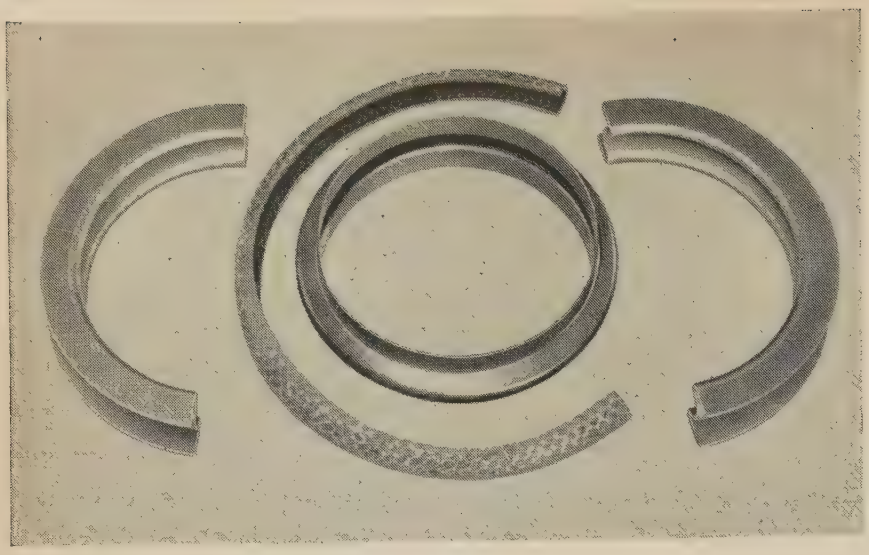
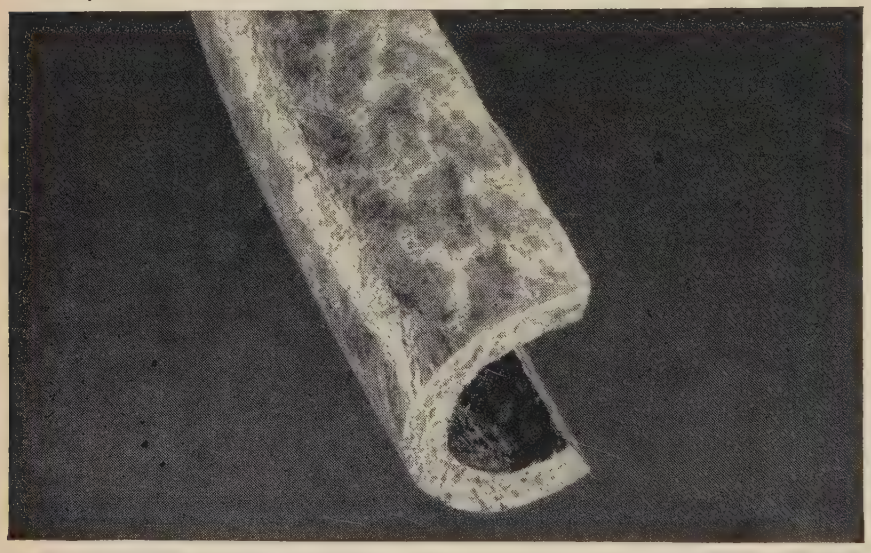


R/M CAPABILITY

develops Teflon-impregnated asbestos insulator spacer for duct support assembly in jet



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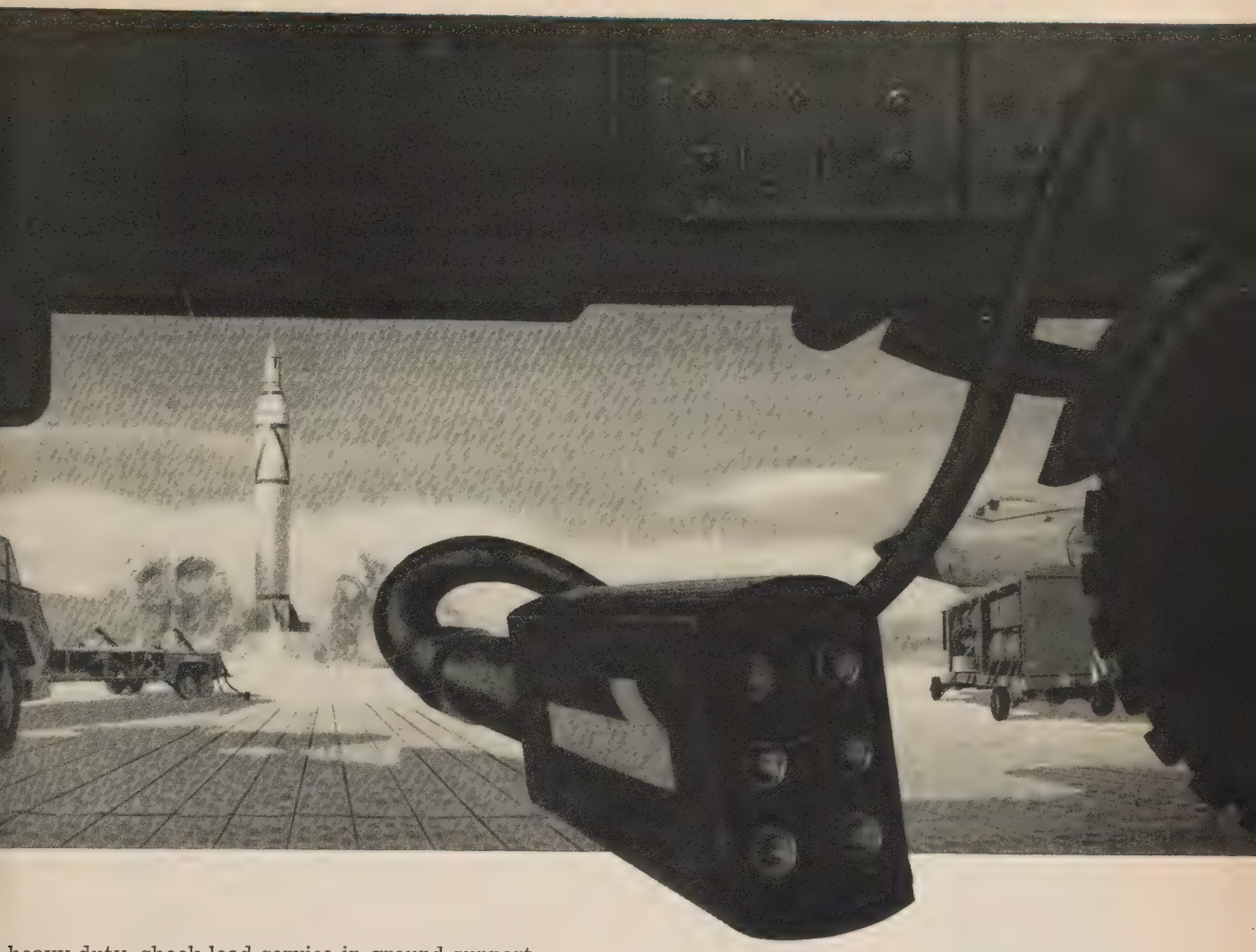

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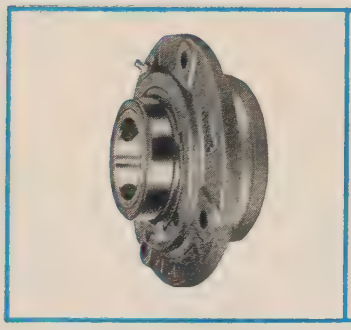

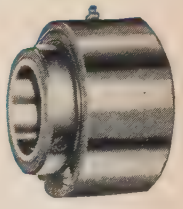

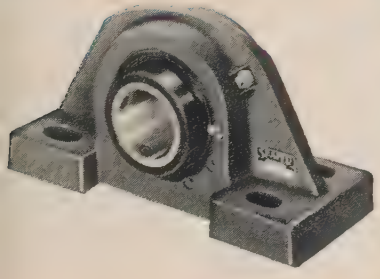

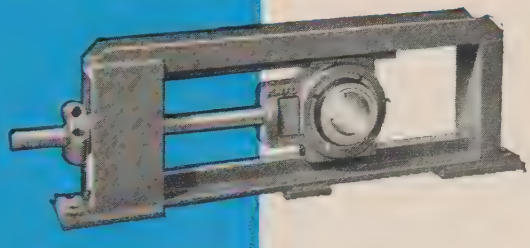

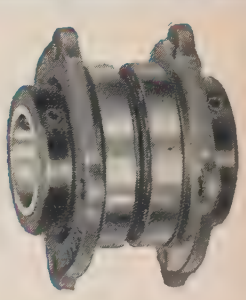

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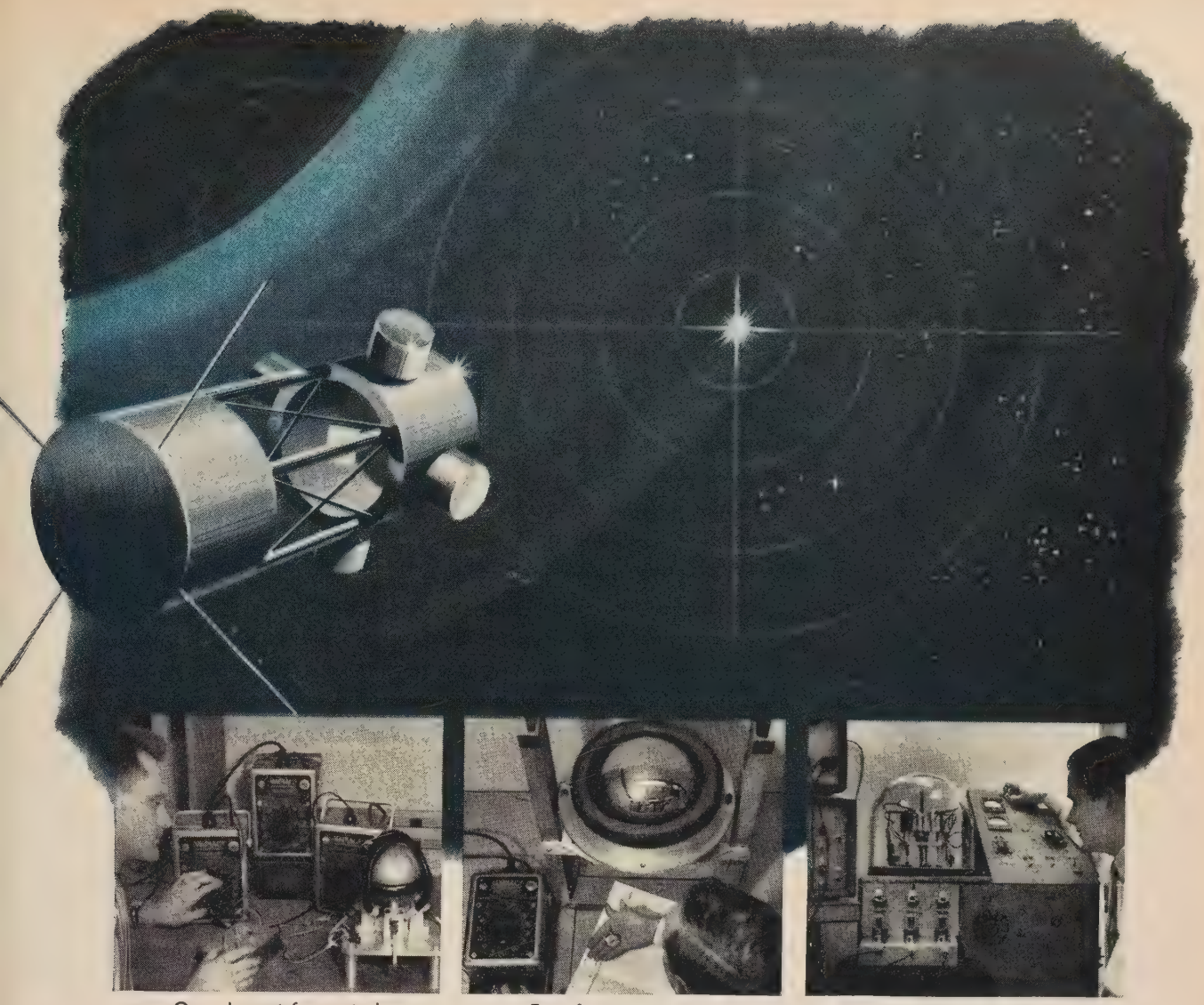

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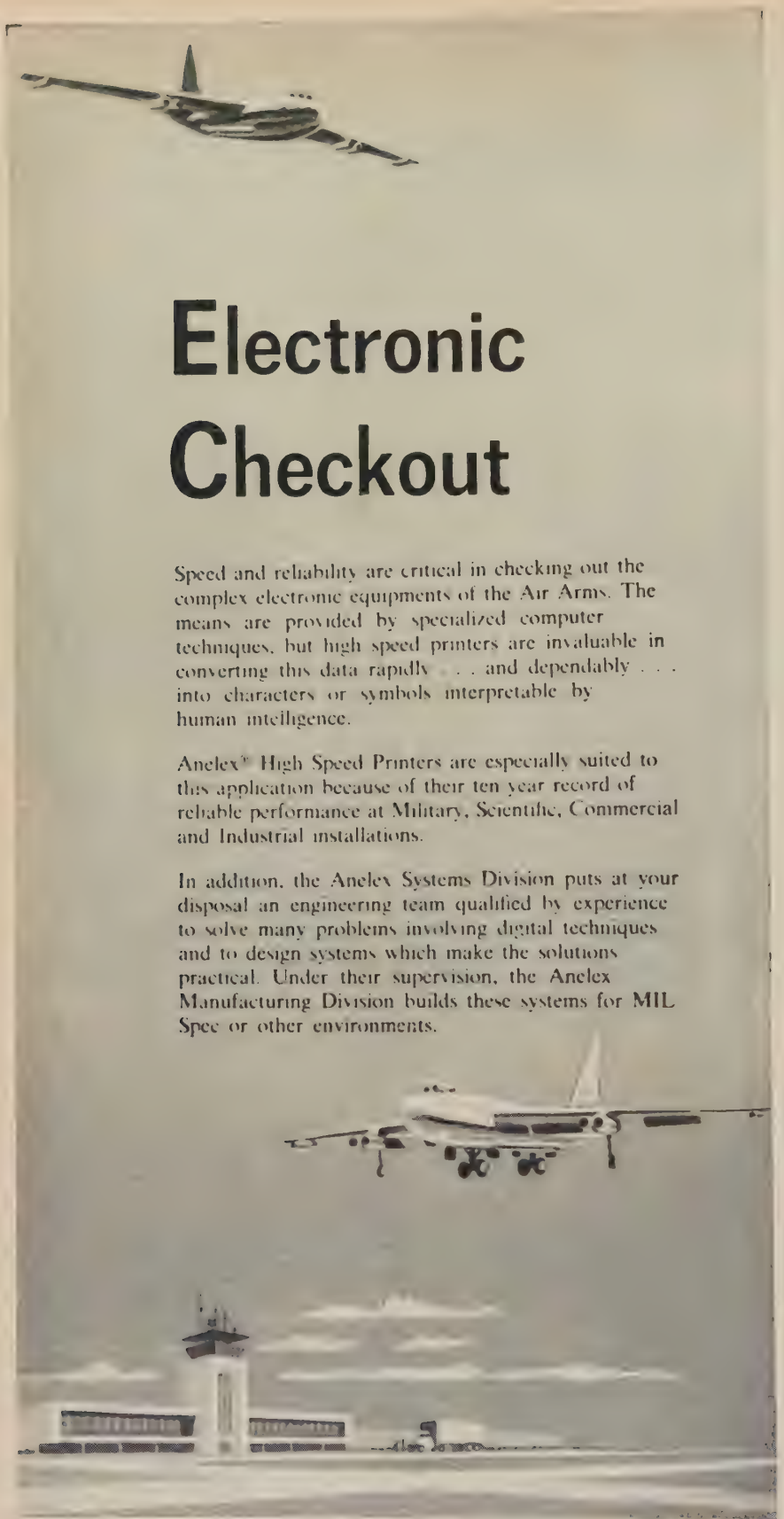

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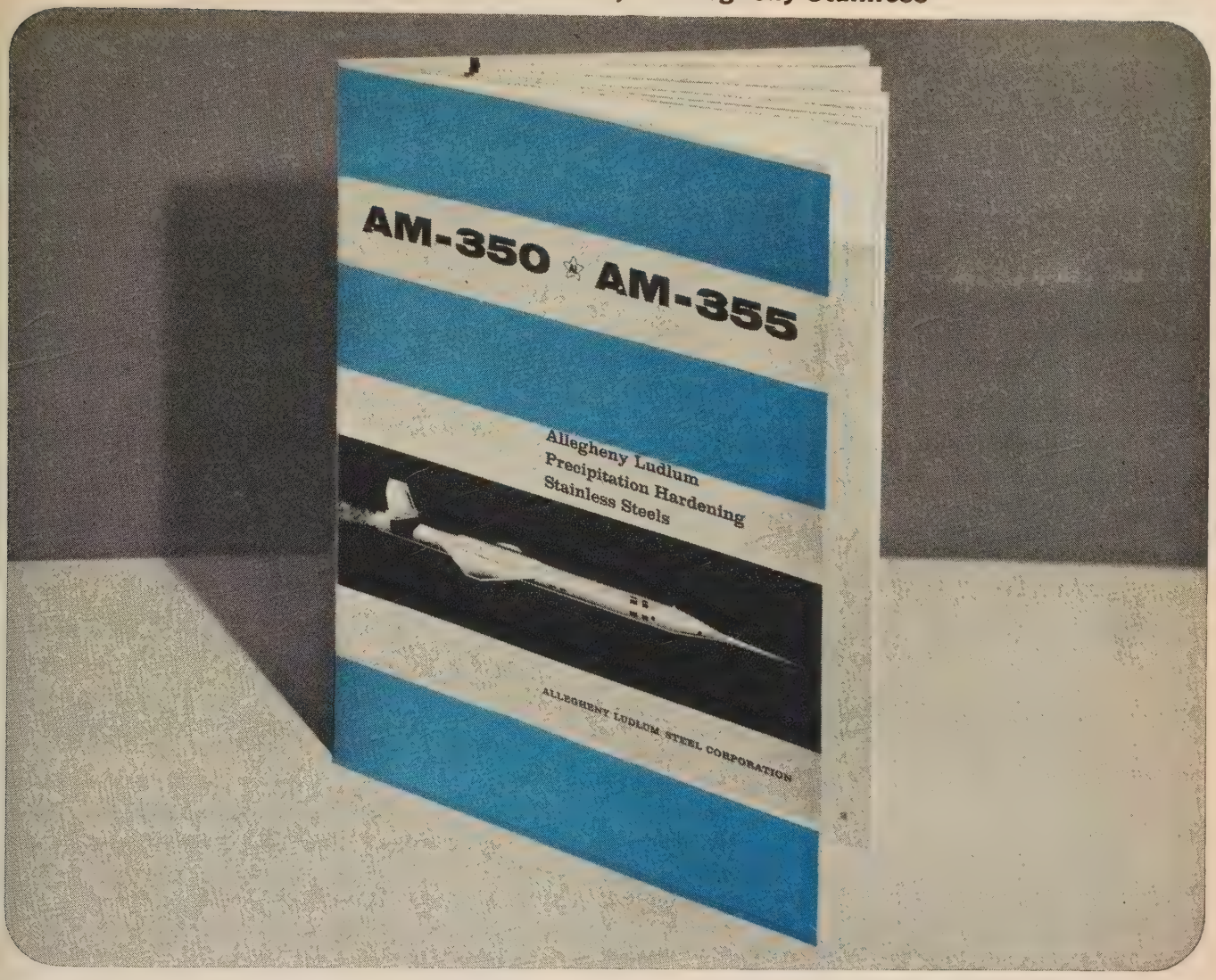

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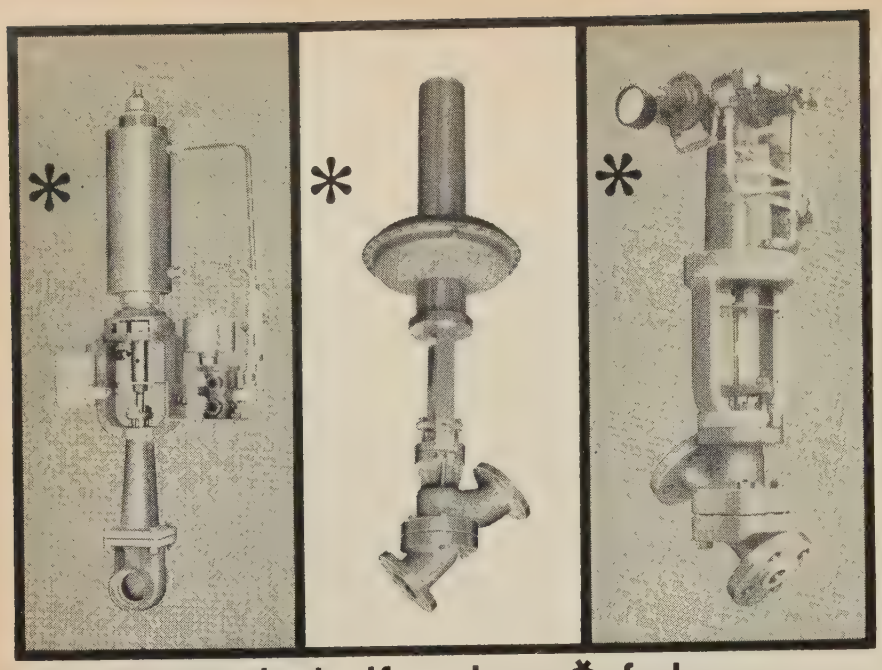

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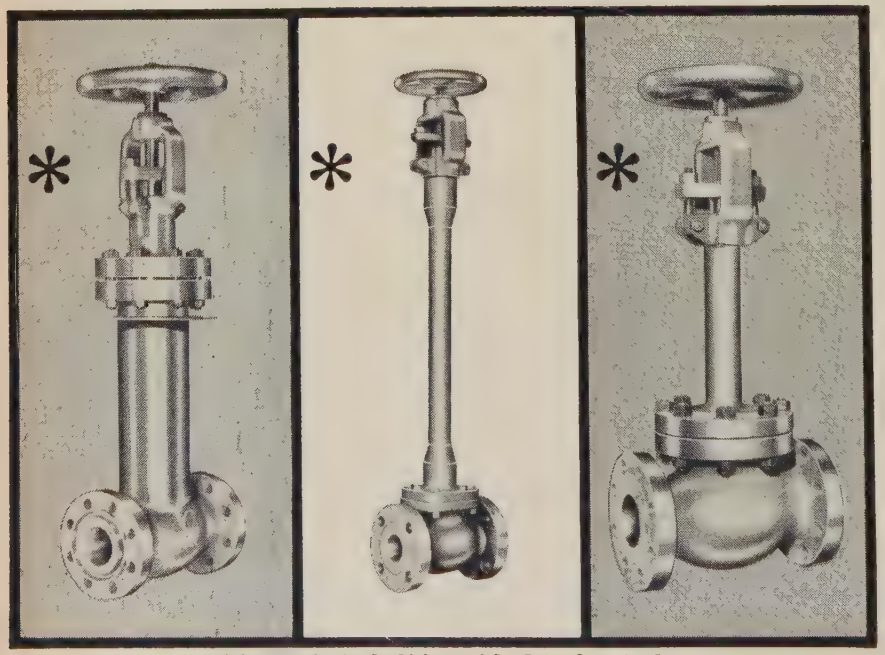

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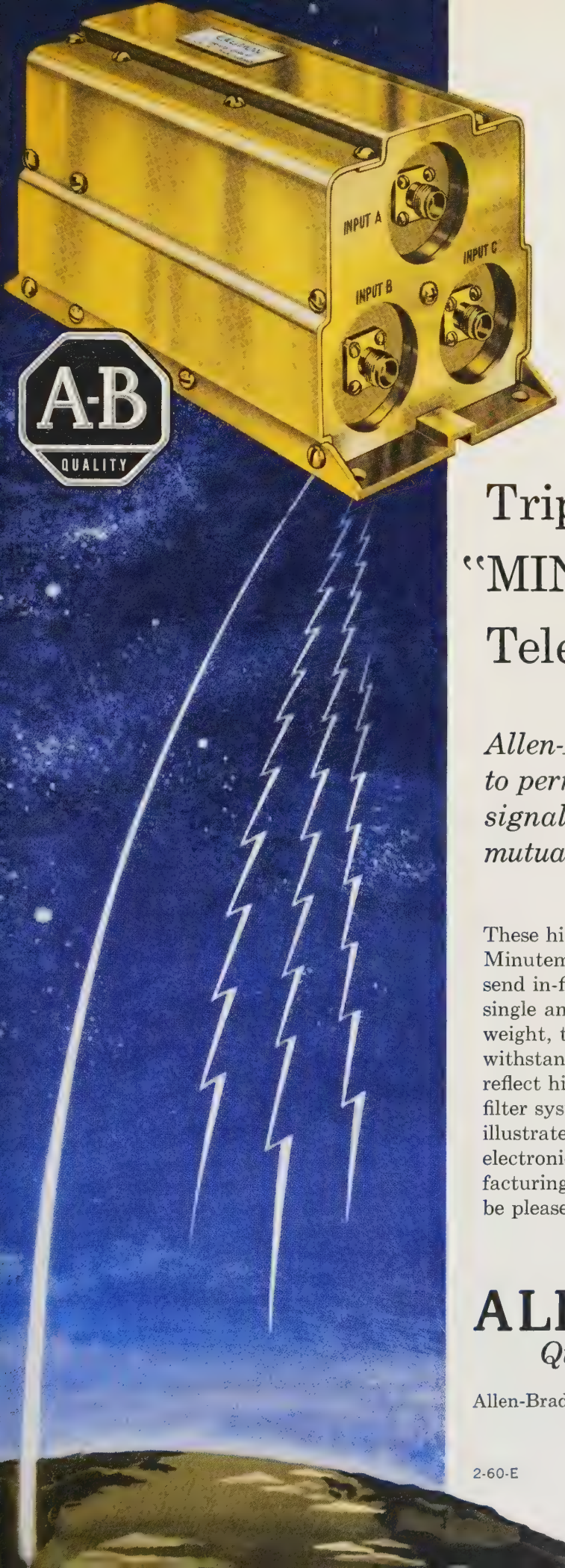

SPECIFICATIONS

Range	Telemetering Band (216—260 Mcps)
Passband	±0.300 Mcps
Input Power	50 Watts max
Insertion Loss in Passband	≤1.25 DB at 125°C ≤1.15 DB at room temperature
VSWR in Passband	≤1.20
Isolation between Adjacent Channels at 5 Mcps Spacing	≥20 DB
Temperature Range	−65°C to +125°C
Vibration	For use in guided missiles; meets military vibration specs

Other power levels and higher frequency ranges can also be provided.

Triple Filter for "MINUTEMAN" Missile Telemetry System

Allen-Bradley Triplexer is designed to permit three simultaneous telemetry signals through one antenna without mutual interference.

These high-efficiency triple filters—employed in the Minuteman Test Program—enable three transmitters to send in-flight performance data simultaneously from a single antenna. Although extremely compact and light in weight, the Triplexer is ruggedly constructed to withstand shock and vibration—and it is gold plated to reflect high temperatures. This highly advanced filter system—developed and built by Allen-Bradley—illustrates their extensive experience in advanced electronic research, and capabilities in precision manufacturing. Allen-Bradley scientists and engineers will be pleased to cooperate in solving your problems.

ALLEN-BRADLEY

Quality Electronic Components

Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee 4, Wis.

2-60-E

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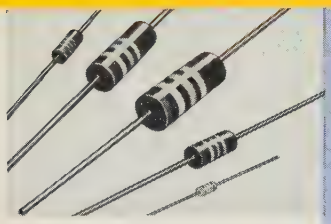
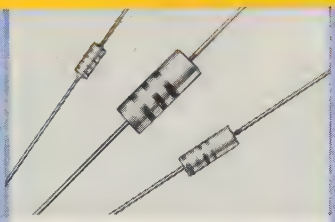
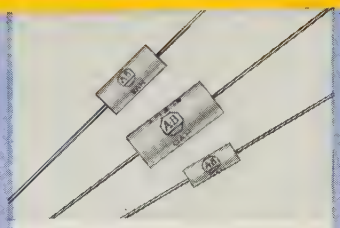
RESISTORS



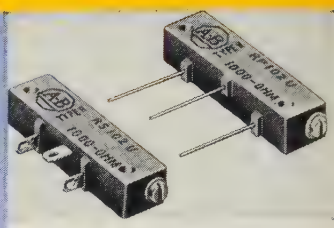
HOT MOLDED COMPOSITION RESISTORS—Quality standard of the industry. Rated at 70°C in 1/10, ¼, ½, 1, and 2 watts. Res. to 22 meg. Tol: 5, 10, and 20%.



HERMETICALLY SEALED in ceramic tubes. Solid, hot molded resistor. ¼ And 1 watt units derate to 0 at 165°C; ⅛ watt unit to 0 at 120°C. Available in values to 22 meg.

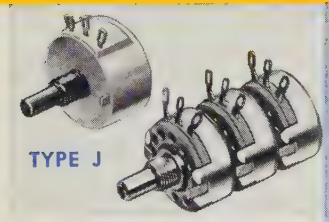


METAL GRID PRECISION RESISTORS—Hermetically sealed. Noninductive. 1, ½, And ¼ watts at 100°C. Tolerances 0.1% to 1.0%. Temp coef ± 25 PPM/°C.

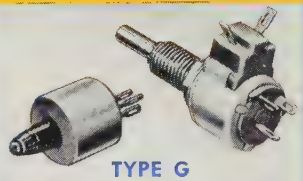


ADJUSTABLE FIXED RESISTOR with hot molded dual track resistance element. Quiet, stable. Rated ¼ watt, 70°C. Values to 2.5 meg. Molded case, length 1¼".

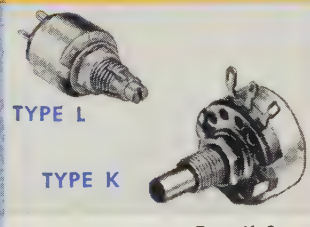
POTENTIOMETERS



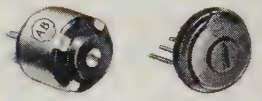
STANDARD—Type J. Solid molded element. Quiet, reliable. Rated 2 watts, 70°C. Values to 5 meg.—less than 10% change in 100,000 cycles. Exceeds MIL-R-94B.



MINIATURE—Type G. Solid molded element. Only ½" in diam. Plain or lock bushing; also with line switch. Rated 0.5 watt at 70° C. Values to 5 megohms. Exceeds MIL-R-94B.

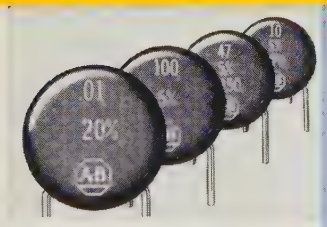


HIGH TEMPERATURE—Type K. Same as Type J but rated 3 watts, 70°C; 2 watts, 100°C; 1 watt, 125°C. Only 1" diam. Type L same as Type G but rated 0.5 watt, 100°C.

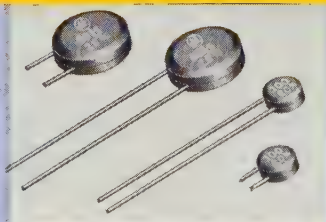


SPECIAL TYPES with solid molded elements. Type F for printed wiring boards has gold-plated terminals. Screwdriver adjustment. Thin Type T uses molded cover as actuator.

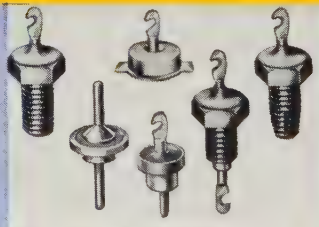
CAPACITORS



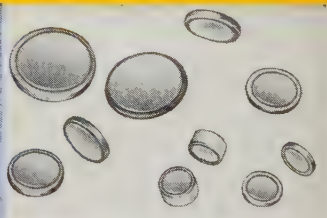
CERAMIC DIELECTRIC capacitors are ONE size—0.55 inch diam for most capacitance values. No "rundown" on leads. Made in many types. Quality appearance.



CERAMIC ENCASED capacitors for use where reliability and superior performance at high temp are important. Rated 500v DC at 150°C. Tol: 5%, 10%, and 20%.



FEED-THRU & STAND-OFF discoidal capacitors for VHF and UHF range. No parallel resonance effects at 1,000 Mcps or less. Nominal values 4.7 to 1,000 mmf.

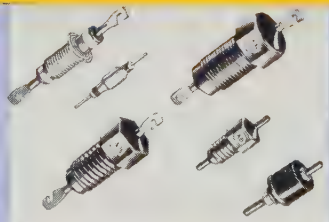


BARE DISC ceramic capacitors for direct mounting in printed circuit boards. Mechanically strong to avoid breakage in handling, installing, and soldering.

FERRITES

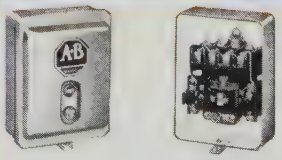
FERRITE CORES including lightweight flared yokes, cup cores, and others for TV. Also, U,E,L, O, and doughnut toroids. Wide range of sizes. All have uniform magnetic properties.

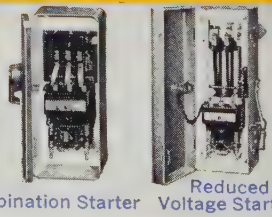
FILTERS



HIGH FREQUENCY low pass cascaded ceramic filters for elimination of radiation. Max ratings: 500v DC at 125°C; RF current 0.25 amp; DC or LF current 5 amp.

QUALITY MOTOR CONTROLS





Allen-Bradley also makes a complete line of manual and automatic, full voltage and reduced voltage starters—plus a full line of pilot controls, such as relays, limit switches, push buttons, pressure and temperature switches, and other devices. Allen-Bradley motor controls are universally recognized for their long life and reliability.

2-60-E

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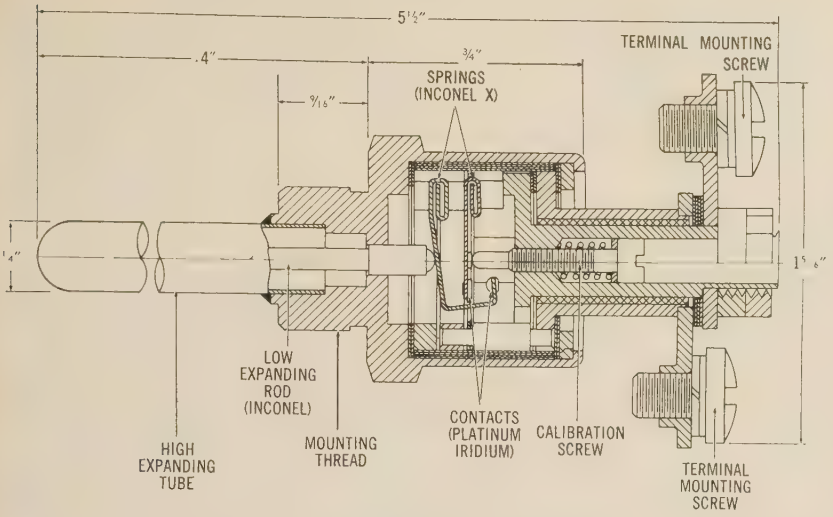
QUALITY ELECTRONIC COMPONENTS

equipment briefs



SUPER-TEMPERATURE SWITCH

A NEW super-temperature switch has been introduced by Control Products, Inc., 306 Sussex St., Harrison, N. J. The "Spec-Stat" has the unique feature of being hermetically sealed though field adjustment is possible.

The 1¾-oz Spec-Stat uses a rod-and-tube probe-type construction. It can be calibrated to 1750 deg F; the minimum calibration temperature is —20 deg F.

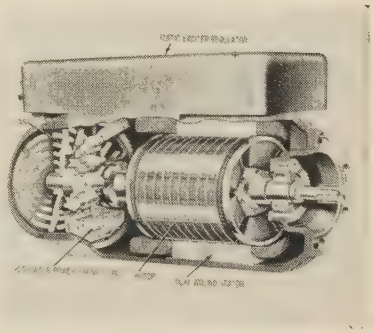
Switch contacts may be arranged to close on rise or fall. Temperature tolerance is two degrees F; temperature differential and repeatability for a given switch is one degree F. An overshoot to 2000 deg F or an undershoot to —100 deg F will not damage the unit. Rating is 1.5 amp at 28 V dc, 110 V ac, resistive loading. Write in No. 67 on Reader Service Card for more information.

PLASTIC ROCKET CASE

RESEARCH tests run by Zenith Plastics Co., Gardena, Calif., show that reinforced plastic structures can be produced with a strength-weight ratio of over 1,000,000 in. Stress levels for a typical plastic rocket case have already gone to a ratio of 1,100,000 in., says Zenith. With refinements in tooling and processing, it is believed that this figure can be increased by at least 25 per cent.

The rocket case that was tested was produced by new methods designed to overcome the problem of size and of joining end closures. Zenith claims that cases can be built from reinforced plastics to a strength-weight ratio of 1,340,000 in.—34 per cent more than the 1,000,000 in. being sought in experimental steels. Developments in high strength glass reinforcements may result in ratios of up to 2,000,000 in.

The use of plastics will cut production costs and save weight, according to Zenith. A reinforced motor case sized for the Minuteman's first stage, for example, can be produced in plastic for 35 per cent less than in 220,000-psi steel and would be 25 per cent lighter and free of notch sensitivity, says Zenith. Write in No. 69 on Reader Service Card for more information.



AC-DC GENERATOR

BOTH ac and dc power for aircraft and missile use can be obtained from the multi-purpose AGE-116 power system developed by Leland Airborne Products Div., American Machine & Foundry Co., Vandalia, Ohio. The generator for the power system has a dual-wound stator with one ac and two dc windings. One advantage of this design, according to the manufacturer, is that it eliminates complexity and weight of the transformer-rectifier package normally used to convert ac output to dc.

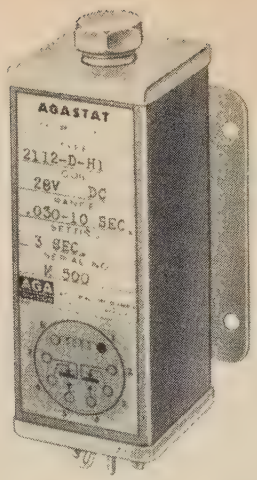
The AGE-116 power system is designed around a continuous-duty, fan-cooled ac-dc generator and an integrated static exciter-regulator network. The network uses high temperature semiconductors and is said to have very fast response under transient load conditions.

Specifications for the generator and regulator are: rated voltage—120/208 ac, 28 dc; rated output—20 kva ac or 14 kva ac and 200 amp dc; speed—7600-8400 rpm; efficiency at rated load—85 per cent; weight—65 lbs.

AC voltage modulation is less than 0.5 per cent at any combination of ac and dc loads to rated load. AC voltage regulation is ±1.5 per cent under the same conditions. DC output regulation is ±2 V from five to 200 amp with no load to full load change and ±1 V (from a constant dc load) from no load to rated AC load. Maximum ripple is less than 0.7 V peak value. Write in No. 65 on Reader Service Card for more information.

more on next page

DESIGN
TIMING
RELIABILITY
INTO
YOUR
CIRCUITS
specify...



NEW MINIATURE AGASTAT®
time/delay/relays

- *Recycling* virtually instantaneous—less than .020 seconds
- Unaffected by Voltage fluctuations (from 18 to 32 volts DC)
- Repeat Accuracy ±5%

This new AGASTAT meets the environmental requirements of MIL-E-5272A. Built to withstand the rugged conditions of missile and aircraft applications. Lightweight—less than 15 ounces. Space saving—4⅝" tall . . . 1 13/16" wide . . . 1½" deep. Adjustable, with time delays from .030 to 120 seconds. Choice of operation for energizing or de-energizing. For complete specifications, write Dept. A37-519

AGASTAT TIMING INSTRUMENTS
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service

produces better molded aircraft/missile parts

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free bulletin 909

contains complete information. Write Formica Corp., a subsidiary of American Cyanamid, 4538M Spring Grove Ave., Cincinnati 32, Ohio.

FORMICA®
Laminated Plastic

a product of
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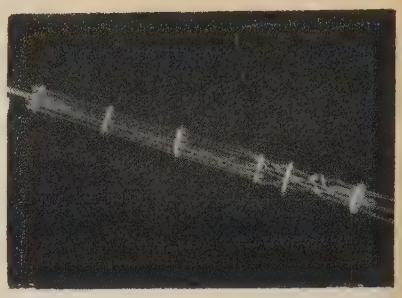

THERMOMETER FOR 600 DEG C PLUS

A PLATINUM RESISTANCE thermometer has been developed by the National Bureau of Standards, Washington 25, D. C., for interpolation between fixed points on the international temperature scale (ITS) above 630.5 deg C (the melting point of antimony). The ITS now is defined for a range from 630.5 to 1063 deg C (the melting point of gold) in terms of a platinum-vs-platinum-rhodium thermocouple. However, this unit can only measure with an accuracy of a few tenths of a degree. The new instrument is expected to provide greater precision and reproducibility at up to 1063 deg C.

Experiments show that it is possible to construct platinum resistance thermometers with drifts of less than 0.001 deg/hr at 1000 deg C. It is necessary to use platinum wire of the highest available purity for the temperature-sending element and to support the element in a strain-free manner with materials containing no silica.

One of NBS's successful designs includes four equally spaced synthetic-sapphire disks supporting the resistor wire. Eight lengths of platinum wire are threaded through holes in the disks. The wires are welded together at the nds to form a single conductor, whose resistance is 0.25 ohm at zero degrees C. The entire unit is encased in a protecting tube of high-purity alumina, forming an instrument about 45 cm long. Mechanical shock tests show that the design provides ample support for the platinum resistor.

The unit was heated at 1000 deg C for 100 hours. During this period, the average temperature coefficient of resistance changed uniformly at an amount equivalent to a total drift of less than 0.1 deg.

more on page 246

When man first steps into the vehicle that will carry him into outer space, it will be with complete confidence.

He knows that he can rely on the extensive testing and preparations that have gone before. Flexonics has played a vital part in these preparations—engineering, designing, and manufacturing metal and synthetic components and systems for hydraulic, pneumatic, liquid oxygen, and fuel applications on America's best-proved missiles and aircraft.

You can draw on this unequalled experience, too, by contacting your Flexonics sales engineer.

Thin wall ducting • Flexible hose: metal, synthetic, Flexon-T (Teflon) • Gimbal, pin, and link joints
Metal bellows and expansion joints • Special-formed stainless steel parts

A-410

Flexonics
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Please send me my personal copy of the Flexonics Aeronautical Engineering Manual, covering in detail Flexonics products and services for aeronautics and space applications.

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WRIGHT Quality

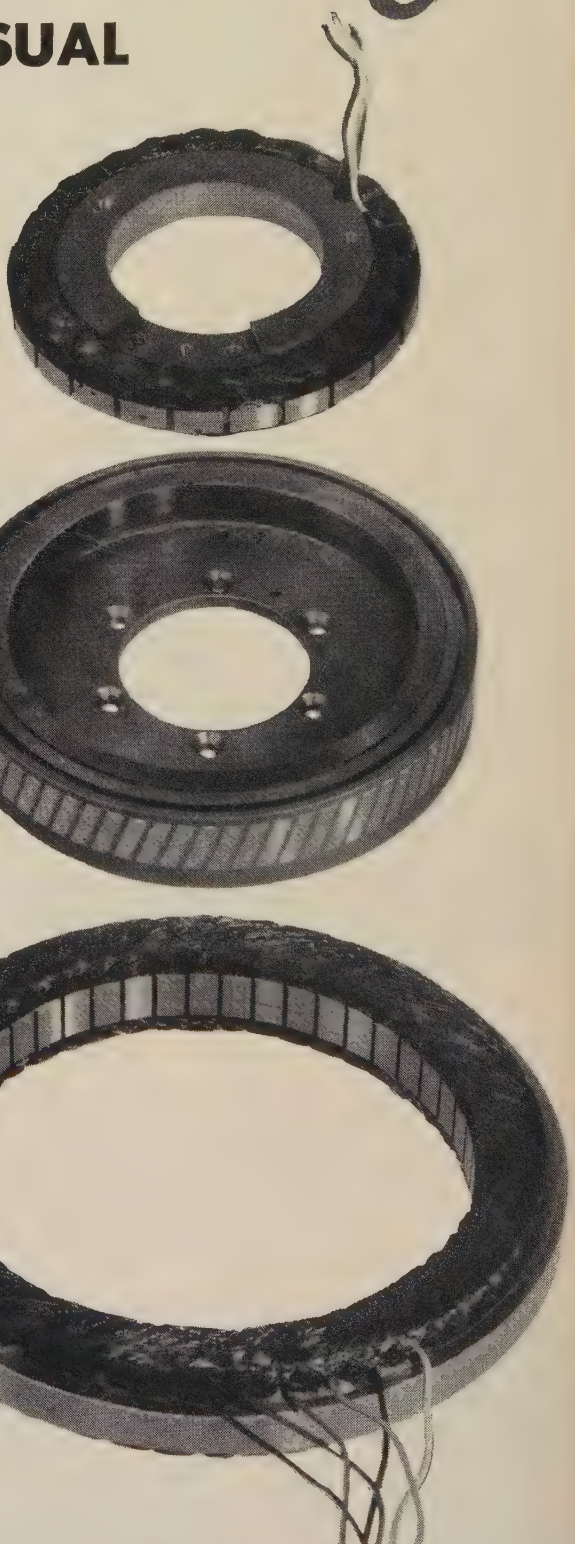
FOR REQUIREMENTS UNUSUAL

These stator and rotor combinations in flat design illustrate Wright Machinery's motor engineering and production capabilities. They are ideal components where the motor is built in and a conventional motor housing is not needed.

One class is the torquer, where the motor never attains running speed. They are made with 20 poles, generally two-phase 400 cycles; and are used, for example, to slave or precess a gyro. A skeleton type multi-pole slow speed servo may have real merit as compared with a high speed control motor with large ratio gearing. Currently, we are producing a two speed motor to operate at 600 and 300 rpm synchrous speeds on 60 cycles.

Another class is for gyro spin motors wherein the stationary wound element is inside, and the rotor is embodied in a fly wheel for high inertia. Wright "pancake" type units can also be supplied as synchros and resolvers.

If your precision motor requirements go beyond the catalog type, consult Sperry Rand's Wright Machinery division.



WRIGHT MACHINERY COMPANY
DIVISION OF SPERRY RAND CORPORATION
DURHAM, NORTH CAROLINA

SALES OFFICES in Durham, N. C.; New Hyde Park, Long Island, N. Y.; and El Segundo, Calif.
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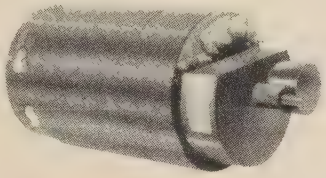
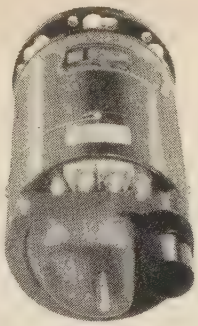
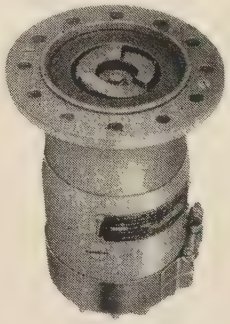


VG-900
Starter-Generator
30 volts 200 amps
8000/12000 rpm
27.5 lbs.



VG-600
Starter-Generator
30 volts 100 amps
4700/8100 rpm
33 lbs.



BW-125
Direct-Cranking Starter
28 volts DC
1 1/2 h.p.
20.5 lbs.

VG-700
Starter-Generator
30 volts 200 amps
4400/8100 rpm
38.5 lbs.

VG-840
Starter-Generator
30 volts 100 amps
8000/12000 rpm
15 lbs.

Application Engineered Starters and Starter Generators Designed for Gas Turbine Systems

Talk to Breeze when you require standard or custom starters or starter generators for your gas turbine system. Breeze is well-experienced in the design and production of compact, lightweight blast-cooled and fan-cooled units up to 200 amp capacities.

Breeze engineers will work closely with you while your gas turbine system is being developed to make certain your requirements are met satisfactorily. Then, depending upon the characteristics of the system Breeze will adapt a field-proven unit or develop an entirely new design for your application.

Produced in large or small production runs, all Breeze standard or custom starter and starter generators are built to meet military specifications.

You'll want a copy of Catalog 88 SG which includes design information on Breeze Starters and Starter Generators. If you have a specific requirement, write describing the details and let Breeze Application Engineers work along with you.

BREEZE MARK

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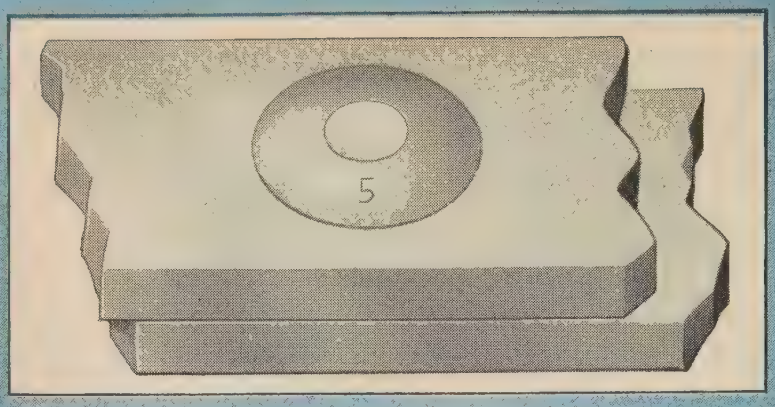

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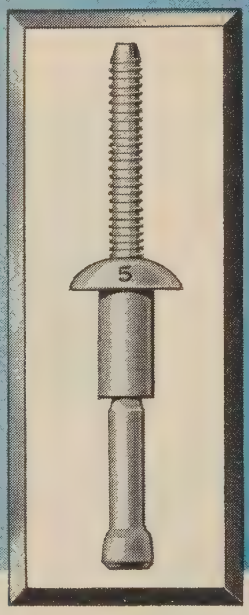
Now

- Serrated Stem Rivets *with*
- Grip Markings on Rivet Head



The new Cherry "9000"* Series MS type rivets are now a part of our standard product line, along with our familiar knob stem rivets.

Cherry is again FIRST to provide grip markings on the rivet head—for easy identification in bins or work boxes, plus positive visual inspection after installation.

Fully approved under MIL-R-7885A, the new Cherry "9000" Series rivets are available in your choice of metals, and are installed with existing serrated stem pulling heads.

For those who prefer serrated stem type blind aircraft rivets, the Cherry "9000" Series completes the line which includes the new Cherrylock "2000" Series Mechanically Locked Stem with flush fracture, the Cherry High Clinch Series rivets—"600", "700", "800"—and the Cherry Standard MS line of knob stem rivets—the "100" and "500" Series. For information write: Cherry Rivet Division, Townsend Company, Box 2157-P, Santa Ana, Calif.

CHERRY RIVET DIVISION

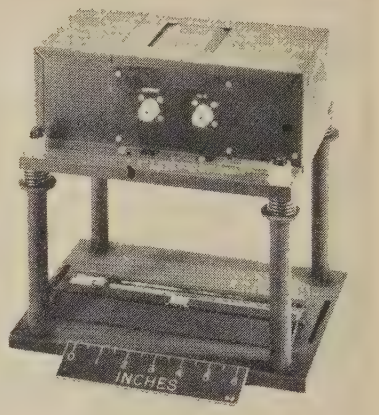
SANTA ANA, CALIFORNIA

Townsend Company

ESTABLISHED 1816 • BEAVER FALLS, PA.

In Canada: Parmenter & Bulloch Manufacturing Company, Limited, Gananoque, Ontario

Write in No. 152 on Reader Service Card at start of Product Preview Section



LIGHT SCREEN FOR MODEL TESTING

A CATADIOPTRIC light screen developed by Research & Advanced Development Div., Avco, 201 Lowell St., Wilmington, Mass., can capture the movement of hypervelocity projectiles as small as 0.22 caliber. Projectile flight can be recorded down to exposures of 0.005 usec.

The light screen is being used in hypervelocity instrumentation systems on ballistic ranges for recording missile attitude and aerodynamic flow. Velocity and drag can also be studied by measuring flight times between two light screens.

The light screen consists of a collimated beam of light that is reflected repeatedly between parallel mirrors before it passes into a photoelectric detector. When the projectile breaks the light screen at any point, a current change occurs in the detector. After amplification, the current change is used to trigger a shadowgraph system that produces a photographic record of the projectile flight.

The photoelectric detector is a photomultiplier tube that provides a low-output impedance from the screen and permits the use of a low-gain amplifier with reduced microphonic characteristics. Baffles minimize stray light reflections and other interference with the collimated beam.

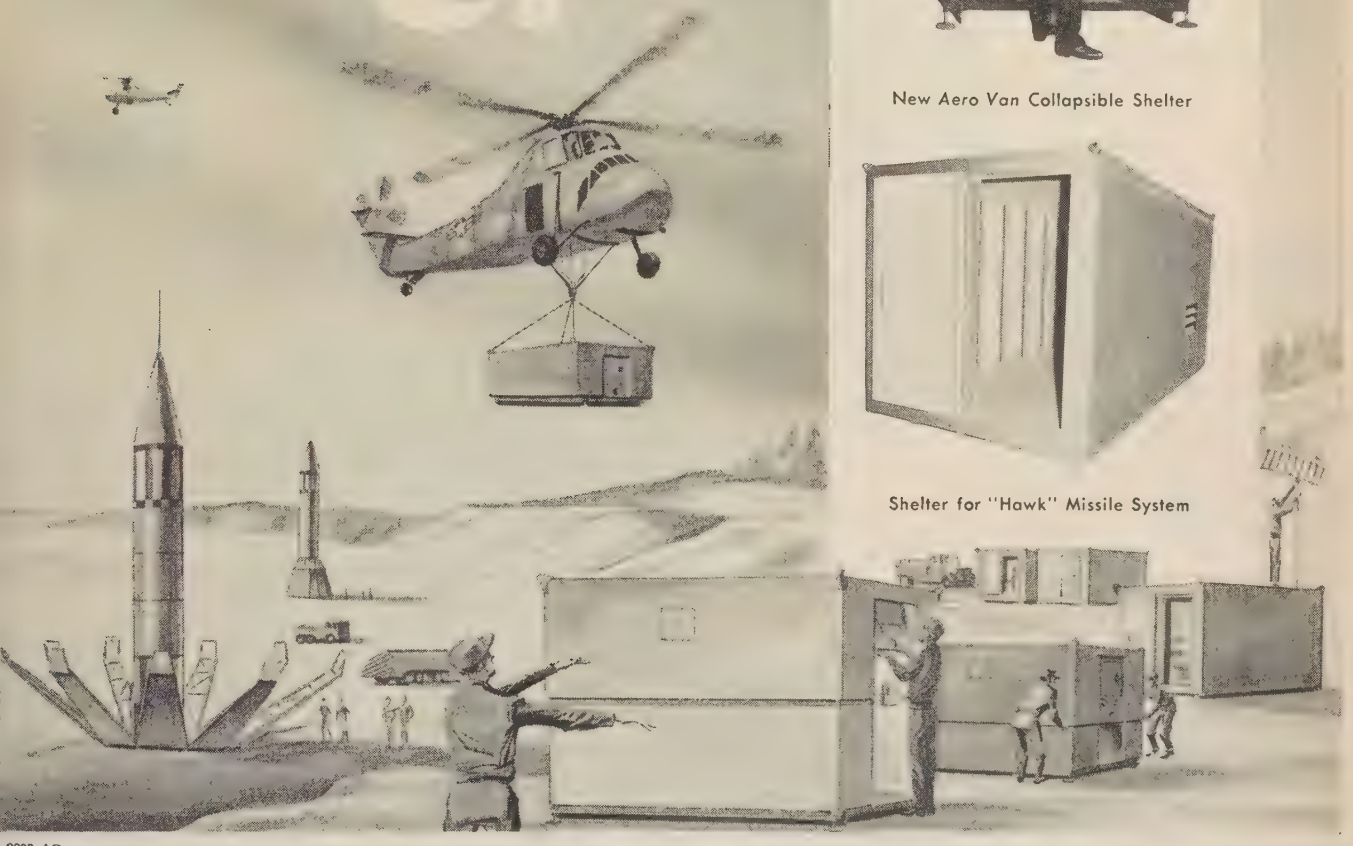
The unit measures 9½x10x6½ in. and has a sensitive screen area of 6x6 in. The effective beam width interrupted by the projectile is ¾ in. in any part of the 6x6 field, giving maximum output over a wide range of projectile sizes. Write in No. 63 on Reader Service Card for more information.

advanced GSE shelters

by AERONCA

New Aero Van Collapsible Shelter

Shelter for "Hawk" Missile System



8893-AC

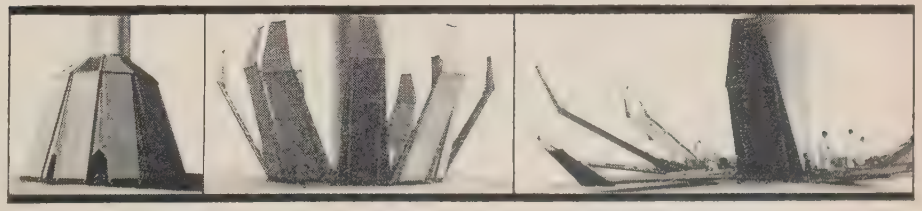
AERONCA DESIGNS, TOOLS AND PRODUCES NEW CONCEPTS IN LIGHTWEIGHT HIGH-STRENGTH AIR TRANSPORTABLE SHELTERS

Created by specialists in aircraft and missile weapon systems and sub-systems, *Aero Van* airborne shelters feature extreme versatility for world-wide applications. These new shelters achieve superior strength-weight ratios as well as interior flexibility through new design and construction concepts. In addition, they are designed for ease of modification and low-cost mass production.

Rugged all-purpose *Aero Van* shelters have been subjected to severe structural, environmental and suitability evaluation tests conducted by Armed Forces testing agencies.

Whatever your GSE shelter requirements, Aeronca can provide a "packaged" capability . . . from original concept to finished product . . . to meet your specifications. *FOR DETAILS, WRITE FOR BULLETIN AS-103.*

ANOTHER CURRENT GSE PROJECT AT AERONCA . . .



These photos show performance tests on a production model of new tactical shelter for "Jupiter" IRBM.

AERONCA

manufacturing corporation

1724 Germantown Road • Middletown, Ohio

Openings for creative R&D Engineers with Missile-Space experience. Write to O. E. Chandler, Mgr. Professional Employment.

Write in No. 153 on Reader Service Card at start of Product Preview Section

Multi-Use Automated Maintenance

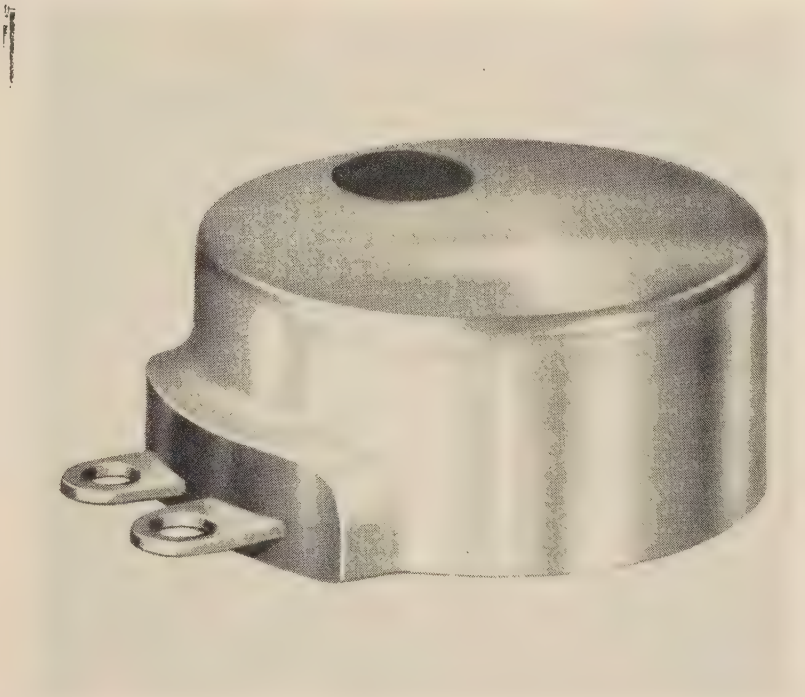
MPTE

The recent demonstration of multi-purpose test equipment (MPTE), developed by RCA under a series of Army Ordnance contracts, highlights *a new dimension in automated multi-use systems support* and culminates a long-term RCA effort in this field. This General Evaluation Equipment is an automated, transistorized, dynamic checkout system. It contains a completely modularized array of electronic and mechanical evaluation equipment, capable of checking a variety of electromechanical devices, ranging from radar subassemblies to missile guidance computers. MPTE provides the stimuli, programming, control, measurement and test functions for the NIKE AJAX, NIKE HERCULES, LACROSSE, HAWK and CORPORAL missile systems and has been extended to other weapons systems related to our defense efforts.

RCA Tmk(s)®

RADIO CORPORATION of AMERICA

DEFENSE ELECTRONIC PRODUCTS
CAMDEN, NEW JERSEY



LOW-DIFFERENTIAL THERMOSTAT
for heating or cooling

Feature Product Award

MAY 1960

Texas Instruments, Inc., Metals & Control Div., 34 Forest St., Attleboro, Mass., is producing the first low-differential precision thermostat that opens *or* closes on temperature rise. The Klixon 4286 thermostats are used on control and warning devices for applications like electronic circuits, servomechanisms, gyroscopes, aerial cameras, etc. They are snap-acting, disk-type units designed to control temperatures within narrow limits and with high reliability.

Continuous temperature exposure limits are —65 to +270 deg F; the temperature setting rate is zero to +250 deg F. The 4286 handles momentary overrides to +325 deg F if designed to open on temperature rise and overrides to +320 deg F if it closes on temperature rise. They are rated from six amperes, 30 V ac-dc to one ampere, 250 Vac. Life expectancy is 250,000 cycles. Switch action is SPST. All models resist to 60 g shock; the wider-differential types (5-9 deg F) resist to 10 g vibration. Weight is about 3.5 gm.

Write in No. 154 on Reader Service Card at start of Product Preview Section

This award is made in recognition of outstanding service performed through the development and manufacture of a product contributing to the advancement of the aerospace industry.

Randolph Hawthorne
Editor

product preview

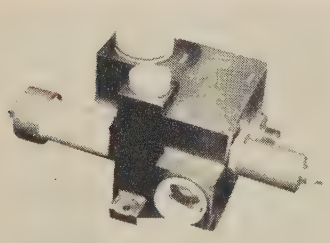
TRANSDUCERS
for unit-to-unit tracking

These transducers were designed to provide unit to unit tracking with a maximum error of 0.002 in over a one in range. The null position is constant within 0.001 in from unit to unit and varies a maximum of 0.001 in within the temperature range of —65 deg to +300 deg F, says **Vinson Engineering & Sales Corp., Dept. S/A, 8044 Woodley Ave., Van Nuys, Calif.**

Other specifications include linearity of 0.15 per cent and sensitivity of 0.88 V/in/V. Secondary impedance is 28 ohms, and recommended input voltage is 8-10 V at 400 cps.

Write in No. 433 on Reader Service Card

VALVE
offers weight reduction



A valve that combines high-pressure hydraulic relief, pressure reducer, and check valve has been designed with size and weight reduction in mind, according to **Vinson Engineering & Sales Corp., Dept. S/A, 8044 Woodley Ave., Van Nuys, Calif.** The A-70198 valve operates at pressures up to 4000 psi and over a —65 to +275-deg F range.

Although it was designed for spec MIL-O-5606 hydraulic fluids, the valve may be adapted for other hydraulic fluids.

Write in No. 434 on Reader Service Card

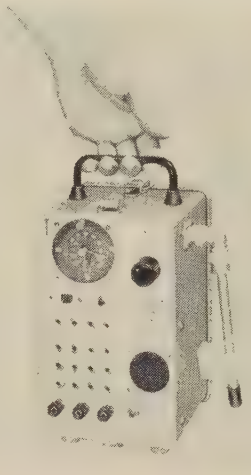
WIRE TERMINALS
reduce costs

Wrap-A-Wire terminals, which can accommodate one or more leads, reduce labor costs and speed production of assemblies such as connectors for coil forms and printed circuit boards, says **Malco Mfg. Co., Dept. S/A, 4025 W. Lake St., Chicago, Ill.** The terminals are easily inserted and fastened, and the single square lug prevents turning.

The units can be supplied in special plating or material.

Write in No. 435 on Reader Service Card

TIME STANDARD
is battery-powered



A portable, self-powered secondary time standard, said to be the first developed, may be used for precisely timed, On-Off control of recording instruments, telemetering transmitters, and other equipment located in remote areas. The completely transistorized device is accurate to ±16 sec per year, and can supply a switching function at 15-, 30-, 45- or 50-sec intervals and at five-min intervals up to one hr, according to **Zenith Radio Corp., Dept. S/A, 6001 W. Dickens Ave., Chicago 39, Ill.**

Model WWV-1 includes a crystal-controlled AM receiver engineered to receive WWV and other accurate sources of "seconds tick" at any of three frequencies, a decoder, a pulse generator, and a dc-operated clock. The two standard batteries for the radio will last for several months and the 1½-V clock battery lasts up to a year. Weight, with batteries, is nine lbs, and dimensions are 7x11x7 in.

Write in No. 436 on Reader Service Card

SWITCHING SERVO
for acceleration

This acceleration switching valve is said to offer excellent resolution, less than one part 10,000 based on maximum valve input signal; zero hysteresis; frequency response; double integration, and reliability with contaminated fluid, according to **Moog Servocontrols, Inc., Dept. S/A, Proner Airport, E. Aurora, N. Y.**

Inherent design features are said to make it more tolerant of high contamination levels in hydraulic fluids.

Write in No. 437 on Reader Service Card

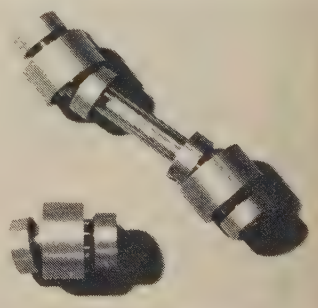
VACUUM FURNACE
for hardness tests

The Model 58-HD high-vacuum furnace will make hardness tests on metals and cermets at temperatures up to 3000 deg F, says **Marshall Products Co., Dept. S/A, 270 W. Lane Ave., Columbus 2, O.** A cylinder of sheet molybdenum is used as the heating element, and it plus its radiation shielding forms a single unit assembly to permit easy removal.

The 38-in high furnace may be readily evacuated at room temperature to a pressure of $1x10^{-5}$ mm mercury by means of a two-in. diffusion pump backed by a four cu ft rotary gas ballast double-stage pump. With this pumping system, normal pressure at 3000 deg F is in the range of $1x10^{-4}$ mm mercury. The furnace requires seven Vac, one phase, 1400 amps, and maximum input to the heating element is 12 kw. The unit features a loading mechanism entirely within the vacuum system, and an indentor movement permitting hardness impressions to be made on three different reference circles.

Write in No. 438 on Reader Service Card

SMALL SHAFT JOINTS
for misalignments



These miniature shaft joints for electro-mechanical applications are used where angular misalignment conditions exist or where a floating shaft coupling is required to compensate for wide parallel and angular misalignment. The joints are recommended for power take off drives from machinery, solenoids, potentiometers and remote control applications, says **Fourdee, Inc., Dept. S/A, P. O. Box 6006, Orlando, Fla.**

Shaft joints are stainless steel precision manufactured to assure tight backlash at high speeds and torque.

Write in No. 439 on Reader-Service Card

more on page 252

Mars products are available at better engineering and drafting material suppliers everywhere

Duralar:

WON'T SMEAR ON MYLAR - ERASES ON MYLAR

Specifically designed to work perfectly on matte-surface drafting film of Mylar®, Duralar is the newest in the complete line of Mars fine drafting products. All are imported from West Germany and are made to meet the highest professional standards. Shown: Mars-Lumograph Duralar pencil and lead—available in five special degrees, K1 to K5; Mars-Duralar Technico with adjustable Duralar degree indicator; Duralar eraser.

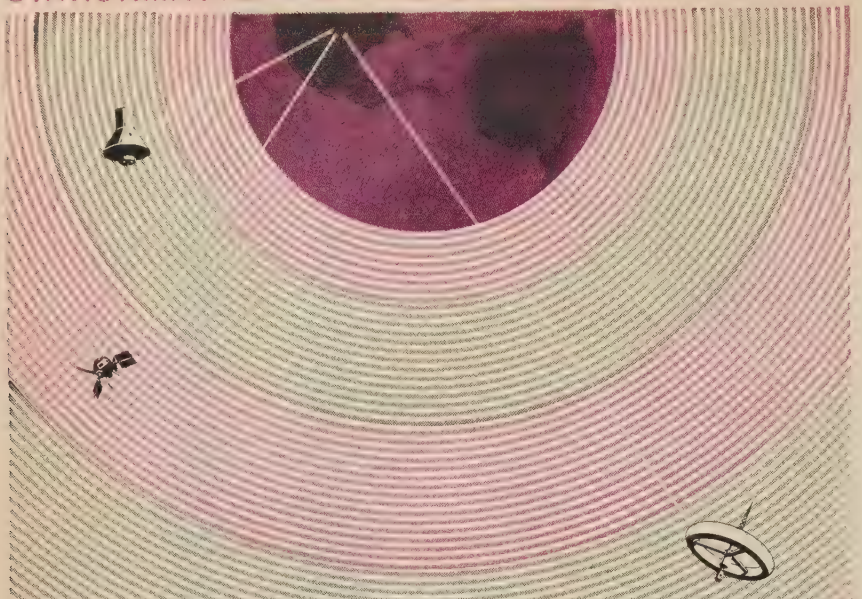
® T.M. for duPONT's Polyester film.

the pencil that's as good as it looks **MARS**

J.S. STAEDTLER, INC.
HACKENSACK, NEW JERSEY

Write in No. 155 on Reader Service Card at start of Product Preview Section

STATIONMASTER FOR THE CROSSROADS OF SPACE



RELIABLE REAL-TIME DATA FOR THE FIRST WORLDWIDE SPACE-VEHICLE TRACKING SYSTEM

because of INHERENT RELIABILITY, CONSTANT FLEXIBILITY, AND FIELD SERVICE WARRANTY

Arnoux's telemetry systems have been chosen for the first Worldwide Tracking System

A NASA project, this program puts the United States in a superior position with the only real-time data needed for the critical task of maintaining a continous contact with astronauts and other space-vehicles. Reliable data, furnished by Arnoux telemetry systems, are continuous and available anytime for useful, applicable evaluation. Arnoux and Astrometrics Divisions provide systems and instruments for telemetry, data reduction, and data acquisition. These particular divisions are contributing to the race for space technology superiority... all Arnoux divisions are on a *task force* basis working to keep **Arnoux Corporation** the leader... as an increasing number of the nation's designers of reliable communications systems look to Arnoux for the newest in dependable telemetry equipment... it's designed with *inherent reliability,* with superior flexibility... Arnoux Field Service guarantees this.

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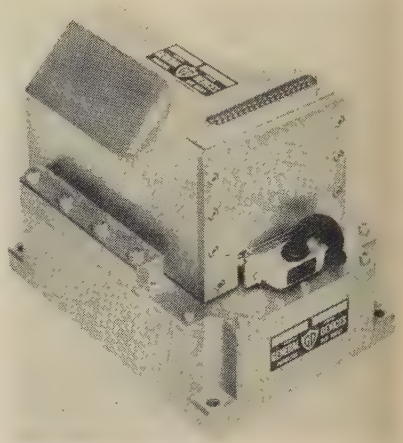
phonetically, say Are New
TELEMETRY

ENGINEERS AND SCIENTISTS . . . IF YOU'RE INTERESTED IN PARTICIPATING IN AN EXCITING TELEMETRY PROGRAM, WRITE TODAY.

Write in No. 156 on Reader Service Card at start of Product Preview Section

COMMUTATOR-GATING UNITS for IRIG channels



The GAG Series high level commuta trogating units are available in all standard IRIG sampling rates and channel configurations. The units will allow high level inputs ranging from 0 to +5 V full scale says **General Devices, Inc., Dept. S/A, P.O. Box 253, Princeton, N.J.**

The unit consists of an electromechanical PERMA-BRUSH type commutator and a hybrid siliconized gating circuit. An IRIG standard negative pedestal signal and a master framing pulse are inserted in the output waveform by an internal gating circuit for decommutation purposes.

Write in No. 440 on Reader Service Card

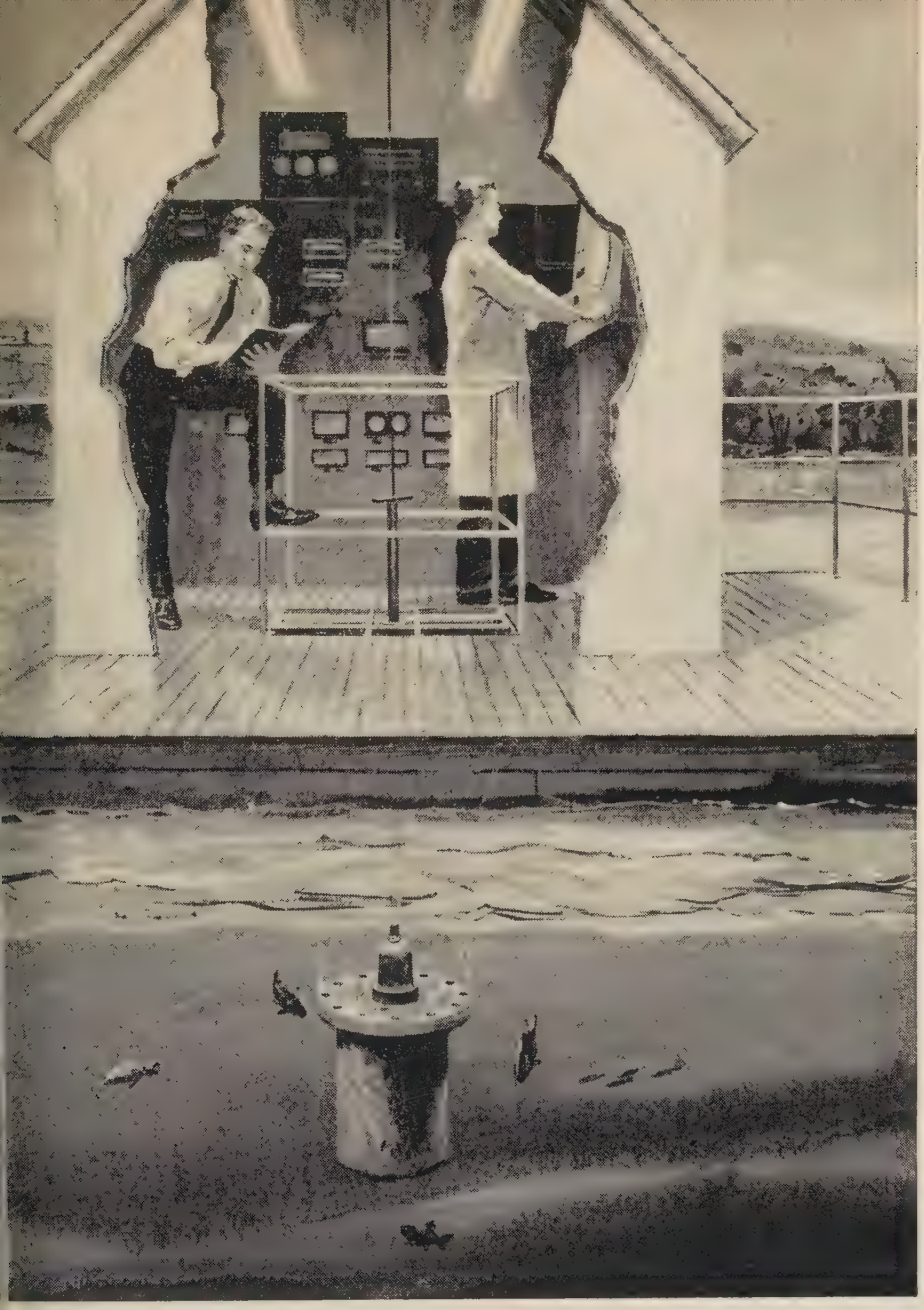
CERAMIC ELEMENTS accept higher temperatures

Piezoelectric ceramic elements useful in sonar systems, ultrasonic cleaners, accelerometers, and other electro-acoustical devices are being made from a modified lead zirconium titanium material that maintains its ultrastable properties at temperatures approaching 350 deg C, says **Universal Dynamics Corp., Dept. S/A, 130 Los Aguajes Ave., Santa Barbara, Calif.** The material, Michelite, may also be used at cryogenic temperatures and is free from transition points falling in between operating temperature limits.

Michelite is reported to display the highest coupling coefficients and sensitivities of any synthetic piezoelectric ceramic materials and to be remarkably free from flaws impairing mechanical strength and electrical performance. It can result in elements about 20 per cent smaller than conventional ceramic bodies and permits operation at far greater power densities per unit volume than previously practicable. The material is available in various shapes, including hollow spheres, cylinders, bars, discs, and blocks.

Write in No. 441 on Reader Service Card

more on page 254

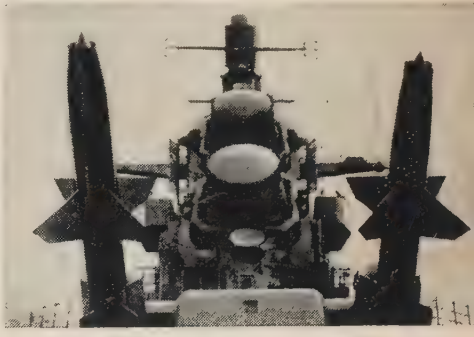


SONAR RESEARCH SITE adjoining Sperry environmental test laboratory duplicates undersea conditions on small scale, simulates targets and myriad problems of anti-submarine warfare. Sonar search device is lowered into "depths" while engineers conduct tests in floating lab above.

PORTABLE FIELD RADAR provides Army with combat surveillance of enemy movements. Headphone signal reveals presence of moving vehicles or personnel in battle area.

TOWER OF STRENGTH in U.S. defenses is strategic network of huge radars for warning of incoming missiles and aircraft. Developed by Sperry in cooperation with the Air Force, system has 70-ton antenna, 85-foot tower.

SHIPBOARD MISSILE GUIDANCE RADARS direct Navy's Talos to target. Other Sperry systems search, track, select right missile for target, aim, fire and guide missile to target—then evaluate "kills"—all automatically.



Detecting the Unseen to Protect U. S. Defenses

Scientists develop new and sophisticated means of listening and searching, to combat the threat of new weapons

ONE OF A SERIES:

THE STORY BEHIND THE STORY
of Sperry's Surface Armament Division

The new nuclear and missile-firing submarines are swift, silent, invisible. They can cruise in the ocean depths for weeks and months, or voyage from the Pacific to the Atlantic under the polar ice cap. The difficulty of detecting them is an advantage when they're ours, and an ever-present threat to our security when they're hostile.

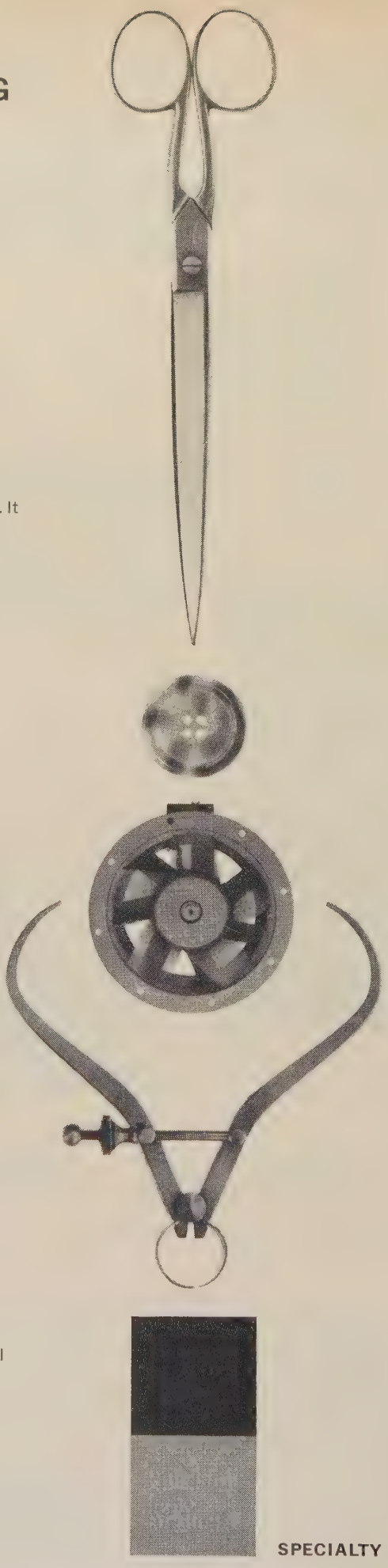
Such problems of detecting and guiding offensive and defensive weapons are being tackled and solved by engineers at Sperry's Surface Armament Division, working in cooperation with all the military services. Advanced techniques in sonar sound detection and torpedo fire control are being applied to anti-submarine defense projects. In addition, sophisticated and advanced radar systems for tactical search, target tracking, missile guidance, area defense and other developments help make effective such weapons as Polaris, Talos, Terrier and Nike Zeus. Sperry also provides supporting systems so important to reliability—and to keeping our defenses in readiness. Surface Armament Division, Sperry Gyroscope Company, Division of Sperry Rand Corporation, Great Neck, N. Y.

SPERRY

Write in No. 157 on Reader Service Card at start of Product Preview Section

EFFICIENT AIR MOVING SYSTEMS ARE 'TAILOR MADE'

There's a highly advanced technology to the business of moving air efficiently, quietly, to precise requirements. It takes, for instance, upward of a million-dollar investment in laboratory, testing, sound-room, designing and experimental capabilities to tailor the **right** solution of the problem to the **total** systems requirement. That's the kind of capability Torrington has. And that's why Torrington is the world's finest in the specialized "science"* of creating air moving systems for the full range of industrial and engineering applications. Cooling thought for the day: Keep the name in mind.



SPECIALTY BLOWER DIVISION

THE TORRINGTON MANUFACTURING COMPANY

SPECIALTY BLOWER DIVISION Torrington, Connecticut

* Knowledge obtained by study and practice—Webster

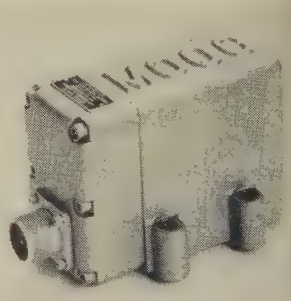
DIGITAL COMPARATOR produces analog signal

Called Comparatrom, this device performs continuous digital comparison of command and feedback signals and produces an accurate analog drive signal. It functions with unusually high speed, accuracy, and resolution due to its essentially digital design, says **United Aircraft Corp., Norden Div., Dept. S/A, 58 Commerce Rd., Stamford, Conn.**

Two models are available—one accepting up to 24-bit parallel binary numbers, and the other up to two 24-bit parallel binary-coded decimal digits. Input data may be presented from a storage register, handset switches, or shaft encoder.

Write in No. 442 on Reader Service Card

SERVO VALVES stress high performance



The 71 Series servo valves, reliable, rugged components with the performance of aircraft-type units, have been designed for use in a wide range of industrial hydraulic servo control systems, says **Moog Servocontrols, Inc., Dept. S/A, East Aurora, N.Y.** The valves operate at system pressures ranging from 500 to 4500 psi.

An integral filter, replaceable in the field, eliminates contamination problems. Valves are available in four sizes: one, 2.5, five, and ten gpm at 100 psi valve drop and 15 ma input current.

Write in No. 443 on Reader Service Card

WIRING JACK in simplified design

The Press-Fit type SKT-100 PC is the simplest available jack for printed-wiring boards, says **Sealectro Corp., Dept. S/A, 610 Fayette Ave., Mamaroneck, N.Y.** The device mounts in a metal angle-iron edging for the board, while the rear right-angle lug fits in a hole for the connection.

Probes with a .080 dia and up to .250 in long can be accepted by the unit, which features beryllium-copper contacts in a Teflon insulator body for long life.

Write in No. 444 on Reader Service Card

more on page 256

← Write in No. 158 on Reader Service
Write in No. 159 on Reader Service Car

BENDIX BRAKES—

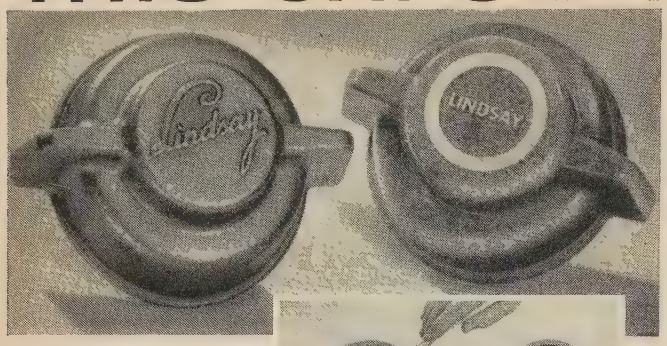
SURE GROUND CONTROL FOR 150-TON GIANTS

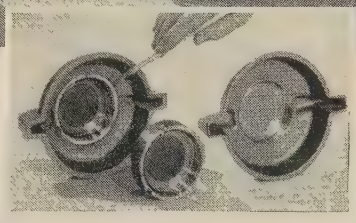
There's good reason why most of today's commercial and military jets rely on Bendix brakes. Products of the world's most experienced brake manufacturer, they are specially designed and built to meet the extra-heavy ground control demands of these high-performance aircraft. In fact, "Brakes by Bendix" signifies safe, sure ground control—*whatever* the aircraft.

Bendix PRODUCTS DIVISION South Bend, IND.

Bendix AVIATION CORPORATION

THIS CAPS IT!





COSTS 25% LESS, WEIGHS 25% LESS, MEETS EVERY SERVICE REQUIREMENT, LOOKS BETTER, AND DOESN'T REQUIRE ANY FINISHING!

This is a "spin-cap", used on Lindsay Water Softeners. It used to be made of brass, like the one at left, above. We now make it of nylon-reinforced premix plastic as shown at right, above.

We suggested the design, and even though we're plastics people, recommended that the brass threads be retained. (Salt used in the water-softener *could* cause mechanical binding of plastic threads.) The threaded brass insert, also our design, (see small photo above) is molded integrally with the cap, to solve that. Tooling required about one-half the time required to tool up for casting.

The big point is, Lindsay Company and their customers are benefiting from a *practical* improvement — *and* saving money!

NOTE: We regularly mail case histories showing new things we're doing with reinforced plastics. If you'd like copies just jot your name and address on this coupon and mail it to us.

You can, too. Send us drawings, photos, or sketches, and tell us what you want to do. We'll tell you, frankly, what is possible and practical . . . help you engineer it . . . and produce it for you!

Yes! Put me on the list to receive Case Histories.

NAME_____

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structural fibers, inc.

FIFTH AVENUE • CHARDON, OHIO

REINFORCED PLASTIC PRODUCTS BY THREE PROCESSES:
• internal pressure molding
• matched die molding
• premix molding

Write in No. 160 on Reader Service Card

TRANSDUCER *uses variable reluctance*

The Model 2203 miniature angular position transducer is designed for use in servo systems for continuous measurement and remote indication of rotary components, such as aircraft or missile control surfaces, says **Bourns, Inc., Dept. S/A, P.O. Box 2112 Riverside, Calif.** It uses the principle of variable reluctance to obtain an ac output as a function of shaft rotation.

The unit has a range of +45 deg, and input voltage of 24 V, 400 cps, and output of six V full scale, or 5.5 +0.1 mv/v/deg of arc. Shaft rotation is continous, and the design provides resistance to severe environmental conditions. No sliding electrical contact is incorporated, and the stepless output provides infinite resolution with a sensitivity of better than 0.005 deg of arc. Life expectancy is more than ten million cycles.

Write in No. 445 on Reader Service Card

COAXIAL PLUGS *need no solder*

A simplified crimping method to facilitate high speed assembly is used for the Crimpee, an RF coaxial plug that requires no solder. It is useful in mobile communications equipment, among other devices, and is readily interchangeable with military PL-259 plugs, according to **Cannon Electric Co., Dept. S/A, P.O. Box 3765, Terminal Annex, Los Angeles 54, Calif.**

Once crimped into place, the connection requires 101.5 lbs of force to separate cable from plug. Assembly is accomplished by crimping the cable braid between two concentric ferrules placed over the cable jacket, an operation that may be performed with a special crimping tool. The Crimpee fits five cables sizes: RG-8/U, -9/U, -11/U, -58U and -59U.

Write in No. 446 on Reader Service Card

GYROSCOPE *is cageable*

A cageable free gyroscope with potentiomenter or synchro signal generator pickoff provides accurate angular intelligence for control and telemetering purposes. The design of the unit assures high performance under environmental conditions; shock, up to 60 g's along the outer gimbal axis, vibration, up to 10 g's and a temperature range from —58 deg to +185 deg F, says **Telecomputing Corp., Whittacker Gyro Div., Dept. S/A, 16217 Lindbergh St., Van Nuys, Calif.**

The assembly is filled with a dry inert atmosphere. Electrical connection is made through one end of the case through a hermetically-sealed connector. Basic unit measures 3 9/16 by 5 7/8 in.

Write in No. 447 on Reader Service Card

POWER PACKS *have high shock resistance*

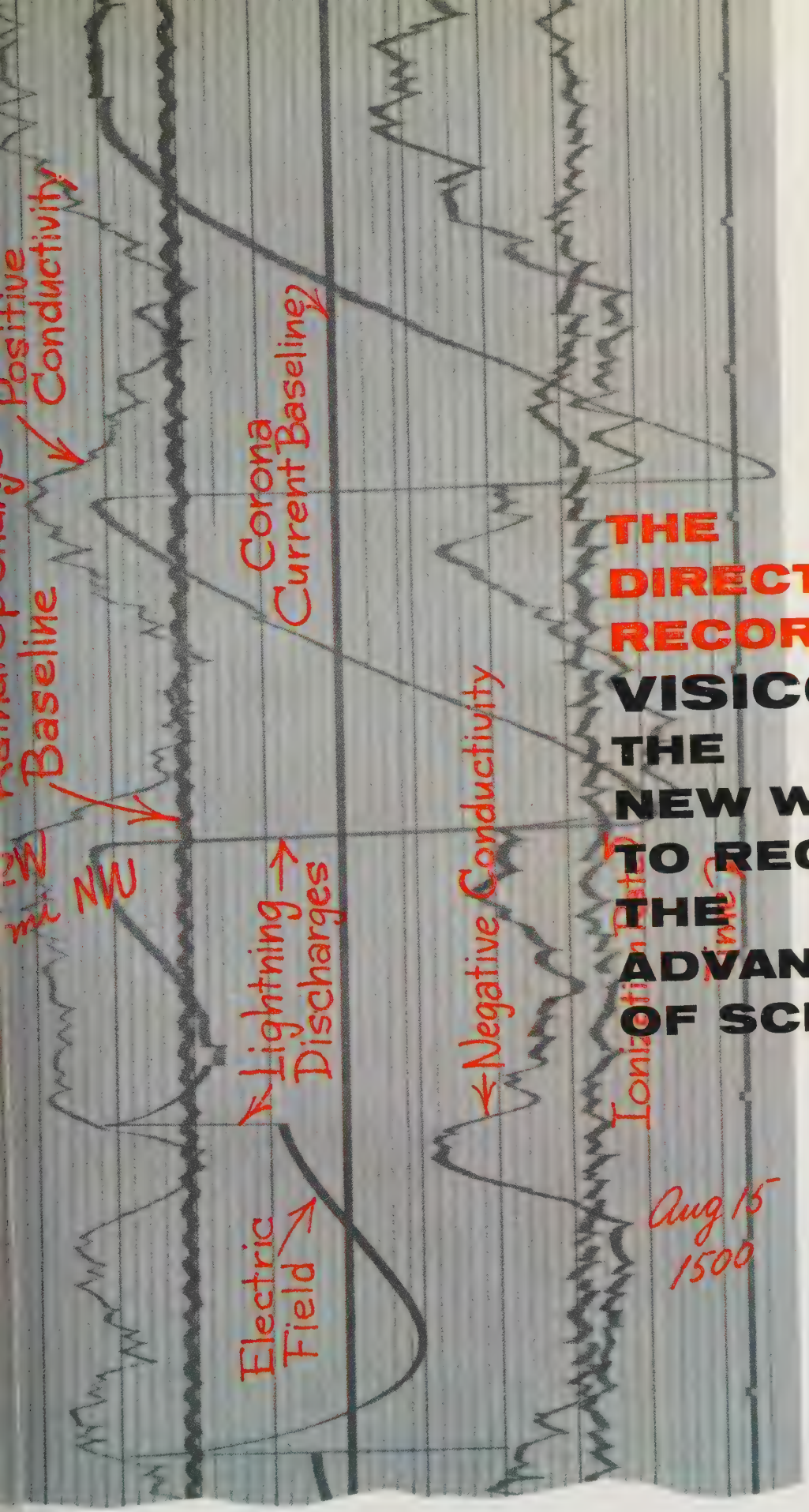
A shock resistance of up to 200 g's has been designed into a new line of potted battery power packs, according to **Gulton Industries, Inc., Dept. S/A, 212 Durham Ave., Metuchen, N.J.** The units may be used in satellites, missiles, rockets, and telemetry applications, and they can be fabricated into a variety of configurations.

The packs consist of permanently rechargeable nickel-cadmium battery cells potted in a specially developed plastic case. The new designs employ all sizes of the Gulton VO button cell battery series, including 80, 180, 250, 500, 800 and 1750 MAH cells, each of which has a nominal rating of 1.2 V.

Write in No. 448 on Reader Service Card

more on page 261

Write in No. 161 on Reader Service Card



THE DIRECT RECORDING VISICORDER... THE NEW WAY TO RECORD THE ADVANCEMENTS OF SCIENCE

HONEYWELL DEVELOPERS OF THE ULTRA-VIOLET PRINCIPLE OF OSCILLOGRAPHY, PRESENT THREE VERSATILE VISICORDER MODELS AND ASSOCIATED SIGNAL-CONDITIONING EQUIPMENT...

Honeywell

MODEL 906 VISICORDER

. . . pioneer in the field of Ultra-Violet direct recording

Two models of the 906 Series Visicorder give you a choice of recording capacity on 6″ paper.

The Model 906 B-1 uses high-sensitivity Series M sub-miniature plug-in type galvanometers that are directly interchangeable among all Honeywell oscillographs of the sub-miniature galvanometer type. Optical arms, therefore galvanometer sensitivities, are an identical 11.8 inches in all instruments.

The 906 B-1 provides for 14 channels of recording including two static reference traces —each channel operating at frequencies from DC to 5000 cps. It has provisions for recording intensity control; trace identification; grid line system (either inches or millimeters) and selectable record speeds (a choice of 5 interchangeable systems, each covering 4 speeds).

The Model 906 B-2 is identical to the 906 B-1, except that it uses solid-frame galvanometers with a capacity of 8 channels, including 2 timing or event-marking channels.

Accessories available for both models of the 906 B include a record take-up unit; record takeup and latensifier; relay rack adapters; and the Visicorder Timing Unit.

Honeywell

MODEL 1108 VISICORDER

. . . newest of the Honeywell direct-recording oscillographs

The Model 1108 delivers direct-writing Visicorder oscillography at the lowest cost per channel. Intermediate in size between the 14-channel 906 and the 36-channel 1012, the 1108 simultaneously records up to 24 channels of data on a record 8 inches wide. This instrument, like other Visicorders, records at frequencies from DC to 5000 cps with unparalleled galvanometer sensitivities.

Pushbutton controls give a choice of 15 record speeds from .05 to 80 inches per second, and time line intervals of 1, .1 and .01 seconds. Such built-in features as automatic record length control, grid-line intensity control, galvanometer spot intensity control, record numbering, reversible record drive, trace identification, provision for remote operation, and many others contribute to maximum convenience in recording high-speed analog data.

As in all Honeywell Visicorders, paper loading, access to the interior, and galvanometer adjustment is easy and convenient.

Honeywell

MODEL 1012 VISICORDER

. . . the most complete, convenient multi-channel oscillograph on the market today

The Model 1012 has been accepted as "the most versatile instrument ever devised for converting dynamic data into immediately visible read-out." It will record up to 36 channels of data simultaneously on 12″ wide paper. It gives complete push-button control of 15 different paper speeds, from 0.1 to 160 in./sec., with automatic recording intensity control. Designed into the 1012 are many other convenience features: daylight paper loading; reversible record drive choice; switch selection of 5 different timing intervals (.001 to 10.0 seconds); simultaneous recording of amplitude reference (grid) lines; trace identification; automatic record length control; record numbering; jump-speed control and provisions for remote and/or multiplexed operation.

Like other Visicorders, the 1012 makes use of the sub-miniature galvanometer. All instruments are readily adaptable to rack and shock-mounting.

Honeywell

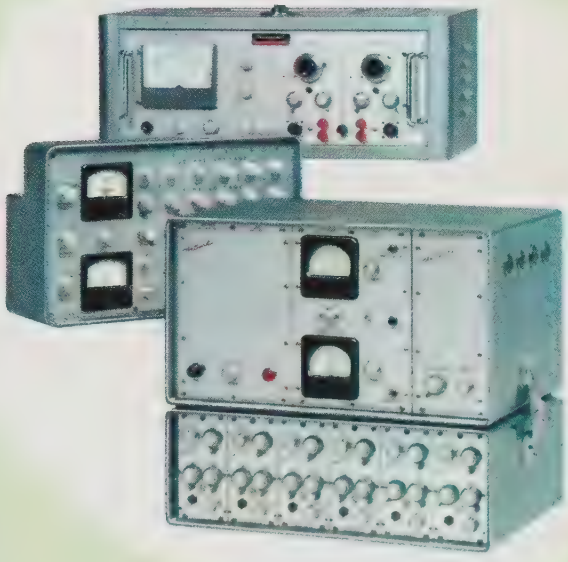
SIGNAL-CONDITIONING SYSTEMS

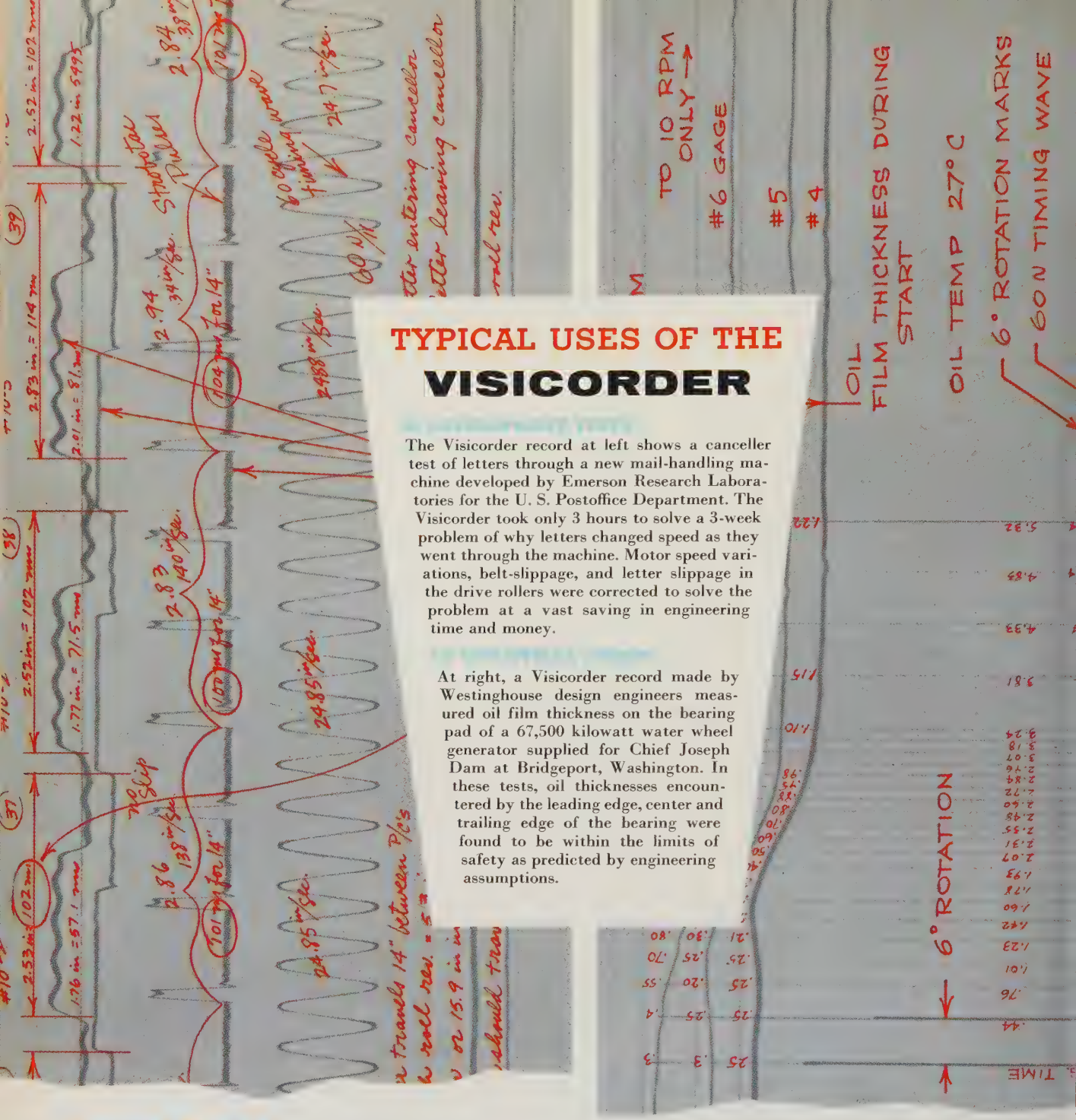
A. The Model 119 Amplifier System . . . a simple and accurate 6-channel carrier amplifier, for use in oscillographic recording, which may be converted to a linear/integrating system simply by installing linear/integrating channels in the same case. The carrier amplifier is designed to amplify signals from resistive, variable-reluctance, differential-transformer, and capacitive transducers. The linear/integrate amplifier is used in conjunction with self-generating transducers such as vibration pickups, etc. The carrier system provides recordings in the 0-1000 cps range at galvanometer amplitudes of 8″ peak-to-peak. The linear-integrate system accommodates frequencies from 5-5000 cps.

B. The Model 130-2C Carrier Amplifier . . . a two-channel unit for use with resistance, reluctance, differential transformer, and capacitive transducers. Produces 8-inch (peak-to-peak) galvanometer deflections up to 1000 cps from as little as 0.5 mv gage output.

C. The Model 82-6 Bridge Balance and Strain Indicator . . . a simple, accurate 6-channel unit for calibrating, balancing, controlling, and measuring static and dynamic phenomena from resistive transducers.

All three of these units are suitable for convenient rack mounting.





TYPICAL USES OF THE VISICORDER

The Visicorder record at left shows a canceller test of letters through a new mail-handling machine developed by Emerson Research Laboratories for the U. S. Postoffice Department. The Visicorder took only 3 hours to solve a 3-week problem of why letters changed speed as they went through the machine. Motor speed variations, belt-slippage, and letter slippage in the drive rollers were corrected to solve the problem at a vast saving in engineering time and money.

At right, a Visicorder record made by Westinghouse design engineers measured oil film thickness on the bearing pad of a 67,500 kilowatt water wheel generator supplied for Chief Joseph Dam at Bridgeport, Washington. In these tests, oil thicknesses encountered by the leading edge, center and trailing edge of the bearing were found to be within the limits of safety as predicted by engineering assumptions.

OTHER USES of the Visicorder . . . as a direct readout unit **IN RECORDING AND MONITORING SYSTEMS** . . . **MISSILE AND ENGINE ANALYSIS** for test stand recording . . . for analog recording **OF TELEMETERED SIGNALS** **IN CONTROL** to monitor reference and error signals . . . **IN NUCLEAR TEST** to record temperatures, pressures, impacts, . . . **IN LABORATORIES** for all-purpose analysis . . . **IN PRODUCTION** for final dynamic inspection . . . **IN COMPUTI** for immediately-readable analog records . . . **IN PILOT COMPONENT TESTS** for rapid evaluation of prototypes . . . **IN** **TESTS** which are non-repetitive in sequence, making oscilloscopes impractical.

Write for your *free* copy of the new 36-page Visicorder Applications Manual, a comprehensive, detailed guidebook to m varied uses of the Visicorder.

Honeywell

Industrial Products Gro

For further information including prices and delivery, write
Minneapolis-Honeywell Regulator Company, Industrial Products Group, Heiland Division, 5200 E. Evans Ave., Denver 22, Colo

POWER SUPPLY for high temperatures

These high temperature power supplies are precision regulated and operate at such temperature extremes as +120 deg C and —55 deg C. Other characteristics include low ripple and low output impedance, says **Arnoux Corp., Dept. S/A, 11924 W. Washington Blvd., Los Angeles 66, Calif.**

Each unit is regulated by silicon transistors and rectifiers, tantalum capacitors and a zener diode reference.

Write in No. 395 on Reader Service Card

TRACKING SYSTEM records radar data

This missile tracking system employs servo repeater units to drive shaft position encoders for encoding range, azimuth, and elevation. It is capable of recording dynamic radar data, correlated in time to 0.001 sec. in a form suitable for direct entry into an IBM 704 Computer, says **Datex Corp., Dept. S/A, 1307 So. Myrtle St., Monrovia, Calif.**

Range resolution is 1 yard in 10^6 yards, and azimuth and elevation 0.2 mils in 6400 mils. Time is recorded with each sample with an accuracy of 0.001 sec.

Write in No. 396 on Reader Service Card

FM SIGNAL GENERATOR for telemetry applications

Model 100 TM Telemetering FM Signal Generator is designed to cover the entire 225-260 Mc Command-Destruct band recently designated by JCEC. This is the only available signal generator meeting all telemetry requirements of carrier frequency, deviation, and modulating frequency, says **Waltham Electronics Corp., Dept. S/A, Waltham, Mass.**

The generator has a total range of 150-280 Mc. Spurious outputs are harmonics of the oscillator only. The instrument is rack mounted and occupies only 10 1/2 in of panel space.

Write in No. 397 on Reader Service Card

INERTIA SWITCH is gravity-actuated

This inertia switch is designed to energize electrical circuits for actuating equipment aboard aircraft and missiles, and it operates when the vehicle's G loading holds a selected value for a specified interval, says **Walter Kidde & Co., Inc., Dept. S/A, Belleville, N. J.** The hermetically-sealed switch may be set prior to sealing to operate at acceleration or deceleration rates between 0.25 to ten G's within 0.01 to ten sec.

Operating voltage is 12 to 30v dc, and the relay contacts are rated at 3.0 amps, resistive. Envelope dimensions are 3½x2⅛x2⅛ in and weight is 0.85 lbs.

Write in No. 398 on Reader Service Card

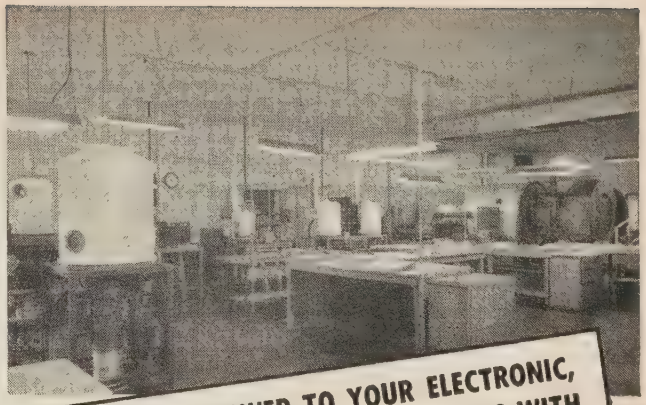
RELAYS have high sensitivity

The outstanding feature of these relays is their high sensitivity of 250, 100 and 50 mw in a crystal can size with 0.2 in grid spacing. Units are rated up to 30 amperes resistance at 28 V dc or 115 V ac. They operate under vibration as high as 30 g's to 2000 cps. with shock ratings of 50 to 100 g's says **Elgin National Watch Co., Electronics Div., Dept. S/A, 2435 No. Naomi St., Burbank, Calif.**

Normal operating voltage range from 1 to 110 volts with coil resistance from 35 to 10 K ohms. Units measure 0.875 in x 0.800 x 0.396 and weigh ½ oz. The temperature range extends from —65 deg C to +125 deg C.

Write in No. 399 on Reader Service Card

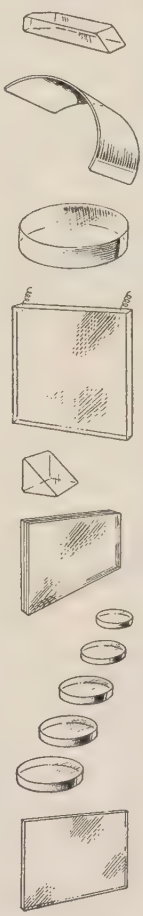
more on page 263



FIND THE ANSWER TO YOUR ELECTRONIC, OPTICAL AND INFRA-RED PROBLEMS WITH

Kinney®

PRECISION EVAPORATED FILMS



Have you explored the possibilities of controlling REFLECTION, TRANSMISSION, ABSORPTION and EMISSIVITY with KINNEY Precision Evaporated Films? Here are advanced techniques, backed by years of research and successful production of optical and electrical films applied to a broad range of surfaces and substances. These development and production facilities are available to you: Front and Back Surface Mirrors—any metals... Low Reflection Films—any wave length... Semi-Transparent Films . . . Dichroics . . . Beam Splitters . . . R.F. Shielding . . . Anti-Electrostatic Films.

KINNEY offers Infra-Red Reflecting Films, designed to your specifications . . . can be deposited upon Glass, Plastic or Metal and many other materials.

KINNEY Infra-Red Low Reflection Films provide peak transmission of desired wave length on Glass, Quartz, Germanium, Silicon, Arsenic Trisulphide and many other materials.

KINNEY provides precise deposition of films for Dark Mirrors and Beam Splitters as well as Absorbing Films.

KINNEY also provides these important Electrical Aids: Anti-Electrostatic Films... Transparent Conducting Films . . . Solderable Films on Glass, Phenolics, etc.

Write for information regarding your specific problems . . . no obligation.

MAIL THIS COUPON FOR YOUR COPY OF BULLETIN NO. 4900.1

VACUUM EQUIPMENT DIVISION
THE NEW YORK AIR BRAKE COMPANY
1327E ADMIRAL WILSON BLVD. · CAMDEN · N. J.

Please send copy of Bulletin No. 4900.1 describing KINNEY Precision Evaporated Films.

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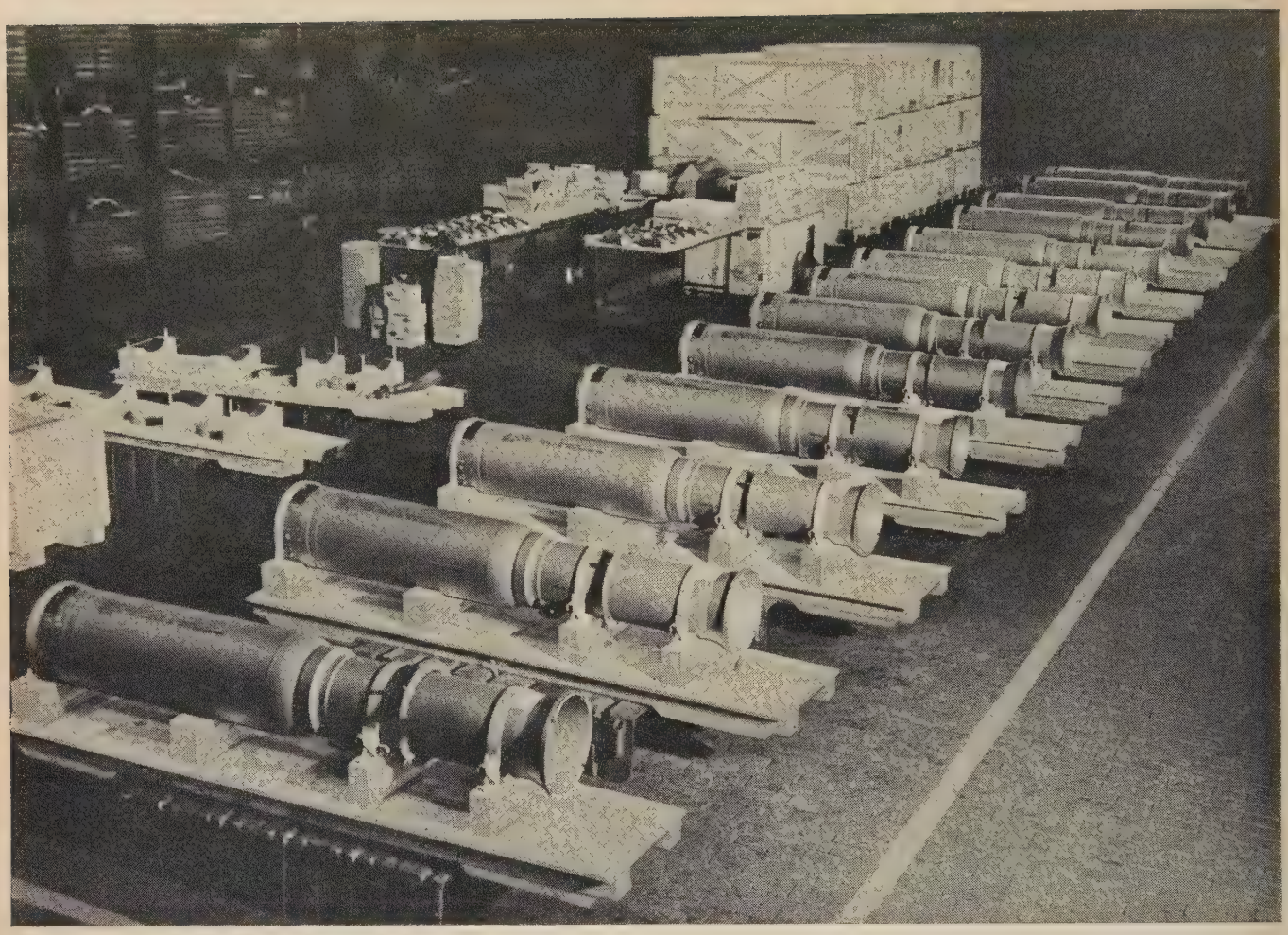
Company_____

Address_____

City_____ Zone____ State_____

Write in No. 162 on Reader Service Card



Part of a shipment of XM10E1 rocket motor metal parts assemblies manufactured by Parish for the Army's Lacrosse missile, a vital weapon in America's arsenal.

PARISH Helps Mass-Produce Missiles to Protect America!

Building *motor metal parts assemblies* for the U.S. Army's Lacrosse missile—being produced by Martin Company—calls for the capacity to produce in quantities a high precision mechanism of the most rigid specifications—so the job went to Parish.

To insure reliability and accuracy . . . to enable the missile—while traveling at fantastic speeds—to hit a target, the motor metal parts assembly cannot vary more than ¼ of 1% of design weight. It must be perfectly balanced and all parts must be completely interchangeable.

Parish has the diversified facilities, the tools and experienced personnel to produce these ultra precision assemblies in substantial volume. If you have a production problem that fits this pattern, write to us. We can help.

PARISH PRESSED STEEL

DANA Division of Dana Corporation / Reading, Penna.

● **DANA PRODUCTS:** Transmissions ● Universal Joints ● Propeller Shafts ● Axles ● Torque Converters ● Gear Boxes ● Power Take-Offs ● Power Take-off Joints ● Rail Car Drives ● Railway Generator Drives ● Stampings ● Spicer and Auburn Clutches ● Parish Frames ● Forgings.

Write in No. 163 on Reader Service Card at start of Product Preview Section

TEFLON TERMINAL has slotted lug

The Type FT-1025 SL Press-Fit Teflon terminal is ideally suited for assemblies requiring potting, or for other sealed-in equipment requiring external connections, says **Sealectro Corp., Dept. S/A, 610 Fayette Ave., Mamaroneck, N.Y.** It has a feed-through hole, which enables the connecting lead to be carried through a chassis or casing.

The unit needs no mounting hardware and is said to provide an excellent seal.

Write in No. 400 on Reader Service Card

COUNTER features low torque

This high-speed miniature counter is a low-cost device originally developed for use in an aircraft fuel flow meter, but it is adaptable to other applications, according to **Veeder-Root, Inc., Dept. S/A, Hartford 2, Conn.** Maximum torque is .010 oz-in at 25 deg C, and maximum operating speed is 1000 rpm.

The external pinion-type device has ⅛-in white characters, and the non-reset wheels are of lightweight Nylon. Suggested areas of use include altimeters, navigation instruments, computer components, and airborne and ground missile radar systems.

Write in No. 401 on Reader Service Card

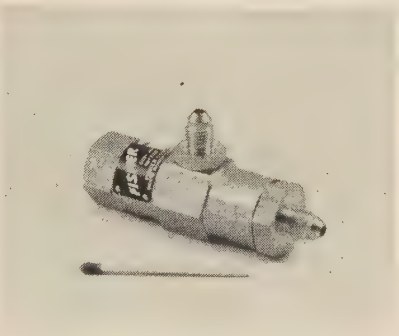
SOLAR CELLS for space vehicles

These silicon solar cells for space vehicles, incorporating an extremely thin, optically-coated coverglass and providing optimum reflection properties and high thermal emissivity, are said to be capable of providing reduced cell temperature and greater efficiency, according to **International Rectifier Corp., Dept. S/A, El Segundo, Calif.**

They provide increased radiative thermal emissivity; protection of cell surface from micro-meteorite bombardment and abrasion; reflection of that portion of the solar spectrum not effective in solar cell electrical conversion, and furnishing an anti-reflection surface to improve the transmission of desired radiation.

Write in No. 402 on Reader Service Card

GAGE PROTECTOR for corrosive fluids



This stainless steel gage protector is for use in pressure systems using corrosive fluids as the pressure medium. They have a maximum operating pressure of 10,000 psi and are available in 28 combinations of inlet and outlet connections, according to **Fisher Controls, Inc., Dept. S/A, 1928 Lincoln Blvd., Santa Monica, Calif.**

Shut-off pressure ranges from —10 to 6000 psi.

Write in No. 403 on Reader Service Card

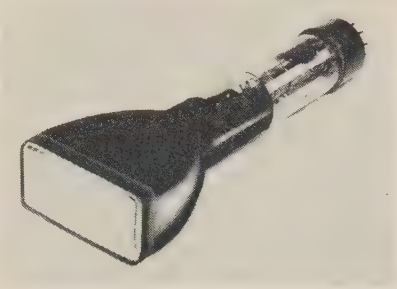
POWER RECTIFIER has ceramic base

Ceramic base rectifiers of compact design eliminates the need for insulating hardware and reverse polarity units. An alumina ceramic disc mounted between the top hat assembly and the hex base electrically insulates the mounting base from the rectifying junction, says **Transitron Electronic Corp., Dept. S/A, 168 Albion St., Wakefield, Mass.**

The ceramic base rectifiers are available in the $^{11}/_{16}$ in hex base configuration with ratings up to 20 amp at 150 deg C case temperature.

Write in No. 404 on Reader Service Card

CATHODE-RAY TUBE reduces parallax errors

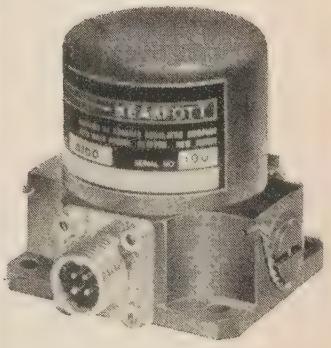


Type 3BDP—is an improved 3 in. rectangular face-plate CRT replacing type 3SP—. Significant features include a precision pressed face-plate to minimize parallax errors and a new gun structure for greater rigidity and improved electrical stability, says **Allen B. Du Mont Lab., Inc., Dept. S/A, 750 Bloomfield Ave, Clifton, N. J.**

Write in No. 405 on Reader Service Card

more on page 265

BASIC BUILDING BLOCKS FROM KEARFOTT



ELECTROHYDRAULIC SERVO VALVE

Kearfott's unique approach to electrohydraulic feedback amplification design has resulted in a high-performance miniature servo valve with just two moving parts. Ideally suited to missile, aircraft and industrial applications, these anti-clogging, 2-stage, 4-way selector valves provide high frequency response and proved reliability even with highly contaminated fluids and under conditions of extreme temperature.

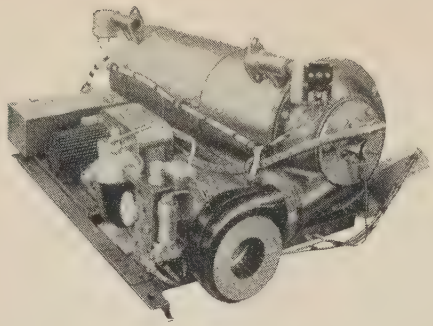
TYPICAL CHARACTERISTICS

Quiescent Flow ..... 0.15 gpm
Hysteresis .. 3% of rated current
Frequency Response 3 db @ 100 cps
Supply pressure....500 to 3000 psi
Temperature-Fluid & Ambient —65° F to +275° F
Flow Rate Range .... .3 to 10 gpm
Weight ..... 10.5 ounces

Write for complete data.

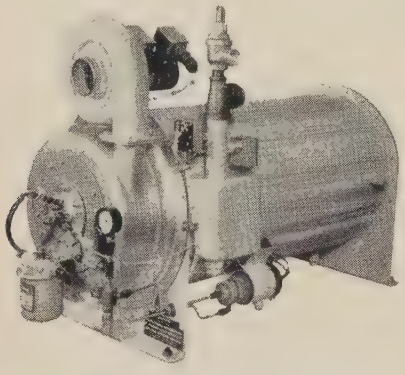
KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

Write in 164 on Reader Service Card



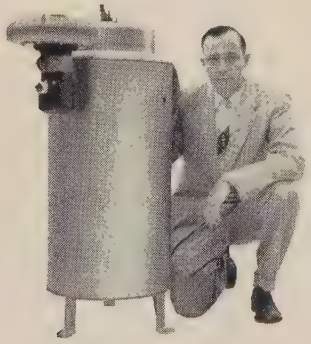
90,000 Btu/hr Janitrol liquid heater

for support vehicle comfort and cargo heating, windshield defrosting. Ideal for use on fire trucks, movers, weapons loaders, personnel carriers, in temperatures to −65°F.



500,000 Btu/hr Janitrol liquid heater

for structures, large vehicles, and for heating decontaminants and cleaning fluids on mobile ice removal units.



1,000,000 Btu/hr Janitrol liquid heater

for heating chemicals during storage and transfer, vaporizing liquids, and in a wide variety of support vehicles and buildings. Approximately 18″ in diameter, 47″ high, weight: 270 lbs.

liquid heater packages for reliable ground support

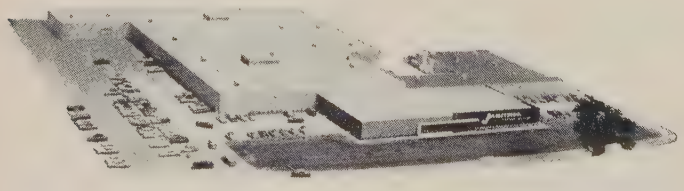
Missile and aircraft support equipment builders use Janitrol liquid heater packages—for comfort and cargo heating, structures, special vehicles, or wherever the convenience of liquid heat can be utilized—because they're built for and have been proved in scores of military applications.

They meet appropriate MIL specifications, are fully qualified, and are supplied in outputs up to one million Btu/hour. They provide any desired amount of heat up to rated output and automatically maintain constant temperatures.

As an example of acceptance, most Air Force crash-fire vehicles are equipped with one or more of these heaters, for engine, chemicals, cargo and crew space heating. Multi-fuel operation is standard, and they perform reliably in multiples for heat requirements which exceed the output of a single unit.

Write for detailed specifications proposals to the Liquid Heater Department, Janitrol Aircraft, a division of Midland-Ross Corporation, Columbus 4, Ohio.

pneumatic controls • duct couplings and supports • heat exchangers • combustion equipment for aircraft, missiles, ground suppo



JANITROL

Write for "Janitrol Resources," brochure on Janitrol capabilities.

Write in No. 165 on Reader Service Card at Start of Product Preview Section

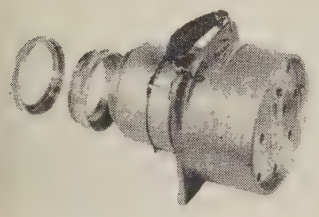
PERMANENT MAGNETS produce high energies

The Hyflux Alnico V-7 is the first commercial permanent magnet to produce energy values of seven million, according to **The Indiana Steel Products Co., Dept. S/A, Valparaiso, Ind.** Applications include lightweight ground and airborne generators and alternators, meters, oscillographs, and missile-borne guidance and recording equipment.

The magnet's energy values derive from a very high degree of crystal orientation. Because orientation and magnetization must be straight, the most common magnet shapes are likely to be cylinders, rectangles, and other prisms, together with some conic or pyramidal frustrums.

Write in No. 406 on Reader Service Card

AIR SAMPLER detects small particles



The Hi Volume Air Sampler, a device that uses filter paper to detect and measure airborne particulate matter, may be useful in rocket and missile fuel development programs, among other applications, says **The Staplex Co., Dept. S/A, 777 Fifth Ave., Brooklyn 32, N.Y.** The portable unit, which features a turbine-type blower, can be used for indoor or outdoor sampling.

It will detect particulate matter with a diameter as small as .01 micron. The standard unit accepts four-in. diameter filter paper, but larger sizes and adapters are available.

Write in No. 407 on Reader Service Card

PULSE COUNTER is very accurate

Positive meshing of the PlanetGear drive in the Model 2010 pulse counter assures completely accurate counting, says **Haydon Instrument Co., Dept. S/A, Waterbury 20, Conn.** The drive transfers numbers through a Nylon cam and roller compensating device.

The drums of the low-torque counter are activated by a stepping motor, and they can be turned flawlessly up to 40 counts per sec. The stepping motor, without ratchets, contacts or springs, is designed for very long life. counter number are $\frac{5}{16}$ in. and the device is available in two-, three-, four-, five- or standard six-drum types.

Write in No. 408 on Reader Service Card

ZENER DIODES meet Mil specs

Three 10-watt zener diodes the IN1353 rated at 13.2 volts, the IN1358 rated at 22 volts, and the IN1361 rated at 29.7 V are now available for military applications says **Motorola Inc., Semiconductor Products Div., Dept. S/A, 5005 E. McDowell Rd., Phoenix, Ariz.**

The units meet or exceed the mechanical and environmental requirements of MIL-E-1/1236.

Write in No. 409 on Reader Service Card

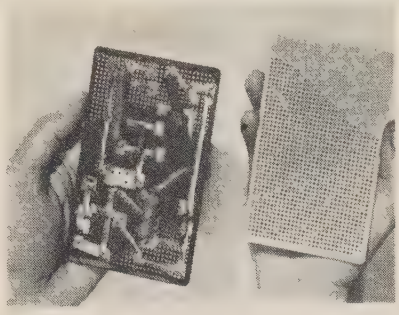
VARIABLE INDUCTOR is small, rugged

These miniature variable inductors, having inductance ranges of .10 to 4700 microhenries, measure 0.400 inches outside diameter and ½ inch in height. They are encapsulated in epoxy resin for protection against climatic and mechanical conditions and meet MIL-C-15305A, grade 1 and class B, says **Essex Electronics, Dept. S/A, 550 Springfield Ave., Berkeley Hts., N. J.**

The unit has stable inductance at extreme temperature variations, high reliability and is lightweight.

Write in No. 410 on Reader Service Card

GRID BOARD for circuit layouts



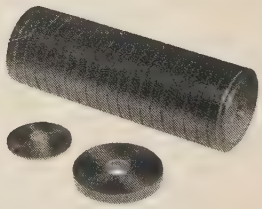
Fotoceram grid board is clad on both sides with copper that can be etched away as desired. The grid for component installation consists of 0.052 in. holes spaced 0.10 in. apart on center, says **Corning Glass Works, Electronic Components D.V. Dept. S/A, Bradford, Pa.**

The boards are $\frac{1}{10}$ in. thick and are available in 3 sizes: 3 by 5; 6 by 8; and 9 by 12 in.

Write in No. 411 on Reader Service Card

more on page 267

BASIC BUILDING BLOCKS FROM KEARFOTT



FERRITES

Kearfott's Solid State Physics Laboratory formulates, fires and machines permanent magnet ferrite materials of various compositions. Typical high-efficiency array utilizes Kearfott PM-3 ferrite material with specially designed pole pieces to produce a design both smaller and lighter than other arrays of equivalent magnetic field strength. Because magnets may be custom engineered to specific requirements, user is not restricted to stock magnet types, thereby providing greater latitude in parameters for focusing arrays. Pole pieces may also be provided according to specification, with the added assurance that, because of special Kearfott design techniques, B axial magnetic fields approximately 10% higher than those generally obtained in standard types may be produced.

TYPICAL CHARACTERISTICS

Peak Magnetic Field Strength	1200 gauss
Period	0.560 in.
Length	5.64 in.
Inside Diameter of Pole Pieces	0.400 in.
Outside Diameter	2.0 in.
Weight	3.2 pounds

Write for complete data.

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

Write in 166 on Reader Service Card

R/M molded rods and tubes for missile research

Take advantage of famous R/M Style 150RPD molding compound in tubes and rods already molded for your developmental work.

You save the cost of dies and molding by machining prototype parts from rods and tubes supplied by R/M in sizes from 1⅛ to 15 in. OD by 15 in. long; or 21 in. OD by 4 in. long.

High-temperature parts made from this molding compound exhibit controlled ablation, good structural strength, excellent thermal-insulating properties, and low thermal diffusivity. Extra-long spinning-grade asbestos fiber provides unusual physical stamina and contributes to high strength-to-weight ratio.

When you have developed and tested your prototype parts, you or your fabricator can then get the desired R/M molding compound in production quantities. Write or call for further information.

RM

RAYBESTOS-MANHATTAN, INC.

Reinforced Plastics Department, Manheim, Pa.

SPECIALISTS IN ASBESTOS, RUBBER, ENGINEERED PLASTICS, SINTERED METAL

Write in No. 167 on Reader Service Card at start of Product Preview Section

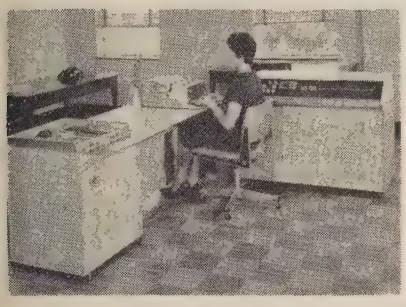
RELAY
has close differential

A network utilizing static devices in conjunction with the Series 1005 microminiature relay has resulted in the ultimate in close differential requirements without the use of mechanical devices, says **Guardian Electric Mfg. Co., Dept. S/A, 1621 W. Walnut St., Chicago 12, Ill.** The dpdt relay is rated at three amps, and it has an operating voltage of 24 V and a release voltage of 22 V, with both ratings plus or minus two V.

Maximum differential between attract and release is two V. Temperature range of the hermetically sealed unit is —65 to +125 deg C.

Write in No. 412 on Reader Service Card

COMPUTING SYSTEM
is fully transistorized



The RPC-4000 Computing System is a general purpose digital electronic computing system which serves both scientific and business data processing needs. The unit has a large storage capacity for data and programs, plus high operating speeds and complete flexibility of input-output, says **Royal McBee Corp., Data Processing Div., Dept. S/A Port Chester, N. Y.**

The system is capable of operating on 9-digit numbers at rates up to 240,000 operations per minute. The memory has a storage capacity of 8,008 words (word length is 32 usable bits). Standard input-output equipment is a tape type writer system complete with typewriter, desk, tape punch-read console and chair.

Write in No. 413 on Reader Service Card

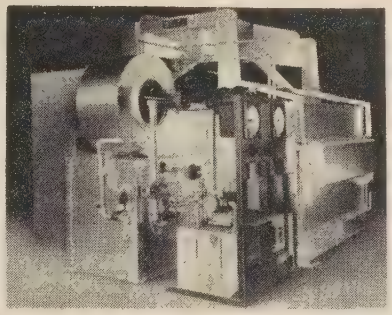
POTASSIUM TITANATE
in blanket form

This low density insulating blanket of DuPont's fibrous potassium titanate in standard thicknesses from one-quarter inch to two inches by 22 inches square at an average density of 16 lbs. cu. ft. is for premium applications. The product is said to show low thermal conductivities up to temperatures of 2200 deg F, according to **Resisto Chemical, Inc., Dept. S/A, Wilmington, Del.**

The insulating properties are due to a high refractive index of the crystalline fibers which block infrared radiation by diffuse reflectance.

Write in No. 414 on Reader Service Card

HYDRAULIC FURNACE
for wing sections



This heat-treating furnace flattens skins of wing sections of material, such as 17-7PH in sizes up to 74x100 in. Flattening occurs during tempering or precipitation hardening, says **Waltz Furnace Co., Dept. S/A, 33, 1901 Symmes St., Cincinnati 6, Ohio.**

Doors open in front and in back of the furnace. Inside are two case-iron dies. The bottom die is stationary; the top, mounted to a hydraulic cylinder with a ball joint.

Write in No. 415 on Reader Service Card

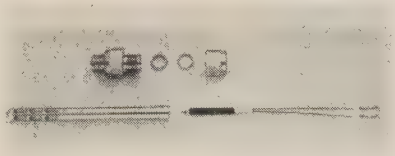
VOLTAGE-CURRENT AMPLIFIER
plugs into oscilloscope

Model 154A dual channel amplifier, has a current-sensing probe which clamps around a wire providing fast measurement and observation of current from 50 cps to 8 Mcps. Sensitivity of the current channel is calibrated from 1 ma per cm. to 1 amp per cm in a 1-2-5 sequence, says **Hewlett-Packard, Dept. S/A, 275 Page Mill Rd. Palo Alto, Calif.**

Sensitivity of the voltage channel is 50 mv per cm, to 20 v per cm. and bandwidth is dc to 10 Mcps. In addition, the unit provides a simple and direct comparison between current and voltage waveforms.

Write in No. 416 on Reader Service Card

TRANSDUCERS
have few parts



This modularized temperature transducer uses few modular elements and replaceable, humidity-proof sensing elements. Tubes are variable in length and can be used for either gas or fluid-immersion applications, says **Arnoux Corp., Dept. S/A, 11924 W. Washington Blvd., Los Angeles 66, Calif.** Outputs of from 0 to 5 volts; ranges from —320 F to 1000 F.

Sensing elements are available in three different materials: nickel-iron, platinum, and thermistor (semiconductor oxides).

Write in No. 417 on Reader Service Card

more on next page

BASIC BUILDING BLOCKS FROM KEARFOTT

INTEGRATING TACHOMETERS

Kearfott integrating tachometers, special types of rate generators, are almost invariably provided integrally coupled to a motor. They feature tachometer generators of high output-to-null ratio and are temperature stabilized or compensated for highest accuracy integration and rate computation. Linearity of these compact, lightweight tachometers ranges as low as .01% and is usually better than ± .1%.

TYPICAL CHARACTERISTICS

	Size 11 (R860)
Excitation Voltage (400 cps)	115
Volts at 0 rpm (RMS)	.020
Volts at 1000 rpm (RMS)	2.75
Phase shift at 3600 rpm	0°
Linearity at 0-3600 rpm	.07
Operating Temperature Range	—54° +125°

Write for complete data.

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

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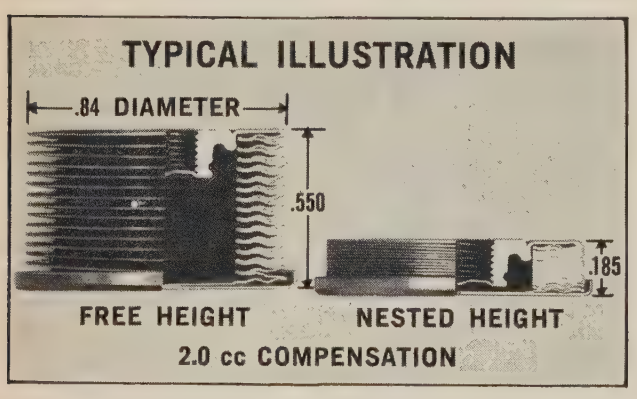
There *is* A Difference
In Welded Bellows...

METAL Bellows

COMPENSATION
PERFORMANCE
PROVES IT!

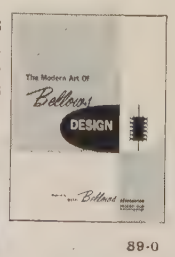
Metal Bellows Design Gives Larger Stroke
...MORE COMPENSATION



Metal Bellows Nest to Shorter Lengths

COMPENSATOR WELDED BELLOWS are finding new applications daily all across industry. Metal Bellows are designing the most versatile, most effective compensator bellows as the graphic cutaway above shows — shorter nesting — more stroke — greater rate of compensation. These are the facts.

Metal Bellows are engineering the right answers for America's defense hardware. Have you seen the difference in welded bellows for your application? Design data and compensator bellows literature on request.



89-0

METAL Bellows CORPORATION

104 MICA LANE, WELLESLEY HILLS 82, MASSACHUSETTS

Pacific Div.—
209710 Knapp St., Canoga Park, Los Angeles, Calif.

Write in No. 169 on Reader Service Card

UNIVERSAL MULTICODER *is solid-state design*

Model 900 telemetering multicoder is usable at any of the standard sampling rates and channel configurations. The unit multiplexes up to 90 channels of information at an input level of 0 to 5 V dc, says **General Devices, Inc., Dept. S/A, P.O. Box 253, Princeton, N.J.**

Weighing less than 3 lbs and measuring only 4 x 4 x 4 in, the multicoder draws less than 4 w from an unregulated 28 V supply and operates for an indefinite period in environments up to 100 deg C. Simultaneous outputs are available in PAM, PDM and magnetic tape recording format.

Write in No. 418 on Reader Service Card

INERTIAL PLATFORM *is lightweight*

This lightweight inertial guidance platform is capable of precise performance under severe environmental conditions. It is designed to operate in very high acceleration environments and at operating temperatures from —55 to +100 deg C, says **General Electric Co., Light Military Electronics Dept., Dept. S/A, French Rd., Utica, N. Y.**

The components have a self-contained temperature control. Use of a non-freezing floatation fluid insures that the system is ready for operation within one minute after power is applied, even at —55 deg. C.

Write in No. 419 on Reader Service Card

RESIN *is heat-resistant*

RF95545 is a resin system with low working viscosity, for potting and encapsulation of electronic equipment which must withstand high temperature or chemical attack. Heat distortion after past cure is at 375 deg F, says **Resin Formulators, Inc., Dept. S/A, 8956 National Blvd., Los Angeles 34, Calif.**

Heat cure cycle is only 2 hr each for initial cure and post cure. Peak exothermic heating of a 1000 gm mass mixture after 8 hr exposure at 77 deg F is only 150 deg F.

Write in No. 420 on Reader Service Card

AMPLIFIER *controls transfer valves*

The low drift, reliability and ruggedness of magnetic amplifiers are inherent in this lightweight servo valve amplifier designed for proportional control of hydraulic transfer valves in missile and aircraft guidance systems, says **Vickers, Inc., Dept. S/A, 1815 Locust St., St. Louis 3, Mo.** The four-in long by 1½-in square device weighs eight oz.

Output is eight ma dc push-pull into two 140-ohm loads, and control signal is 0.5 to two V dc into a 300-ohm load.

Write in No. 421 on Reader Service Card

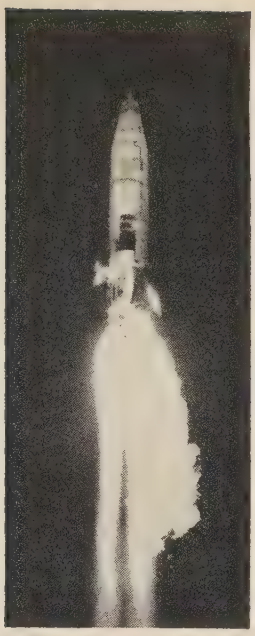
RELAY *has wide temperature range*

The overload rupture, vibration and minimum current requirements of MIL-R-6106-C are met by the Series 3005 hermetically sealed relay, which is useful over a —65 to +120 deg C range, says **Guardian Electric Mfg. Co., Dept. S/A, 1621 W. Walnut St., Chicago 12, Ill.** Standard coil voltage is 24 to 28 V dc, and the unit operates with four-pole, double-throw control switch combinations at ten amps.

It is also available for ac operation up to 400 cps. Vibration resistance is 15 g to 1000 cps, and ten g from 1000 to 2000 cycles.

Write in No. 422 on Reader Service Card

more on page 270



KEARFOTT developed

and now produces

precision floated gyros

for the

Atlas missile.

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

KEARFOTT DIVISION
LITTLE FALLS, NEW JERSEY

GENERAL PRECISION, INC.
OTHER DIVISIONS OF GENERAL PRECISION INC. – GPL-LIBRASCOPE-LINK

Write in No. 170 on Reader Service Card at start of Product Preview Section

PRESSURE BALANCE is miniature

Model 4-332 Precision Pressure Balance is a smaller and lighter transducer which supercedes the two-bellows tranducer formerly used with the Electro-manometer precision pressure measuring system. The unit has been reduced in size to 4x3x2½ in. and now weighs only 2.6 lbs, says **Consolidated Electrodynamics Corp., Transducer Div., Dept. S/A, 360 Sierra Madre Villa, Pasadena, Calif.**

Seven pressure ranges are available from 0-1½ to 0-150 psi differential. Output of the transducer is ±100 V full scale. Combined effects of linearity and hysteresis are less than 0.05 per cent.

Write in No. 423 on Reader Service Card

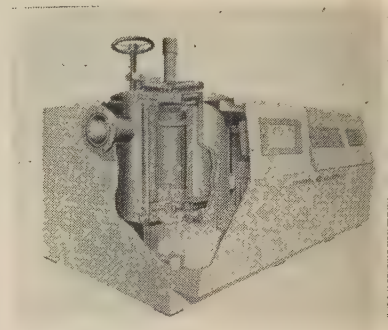
RADAR DISPLAY TUBE has high brightness

Type K1868, 12½ in diam tube is electrostatically focused-deflected and is capable of a high brightness display. The tube requires only 10V grid drive from extinction of a focused non-deflected spot or 7V from raster cut-off for 50 microamp screen current, says **Allen B DuMont Lab., Inc., Dept. S/A, 750 Bloomfield Ave., Clifton, N.J.**

Essentially a radar display device the tube fills requirements existing for low drive, high writing rate applications. Deflection factor of 125 V per in maximum are maintained in both scan directions at accelerator voltages of 5.5-9.5 KV. The special low defocusing deflection assembly maintains high resolution within the useful screen diameter.

Write in No. 424 on Reader Service Card

VACUUM FURNAC radiation shielde

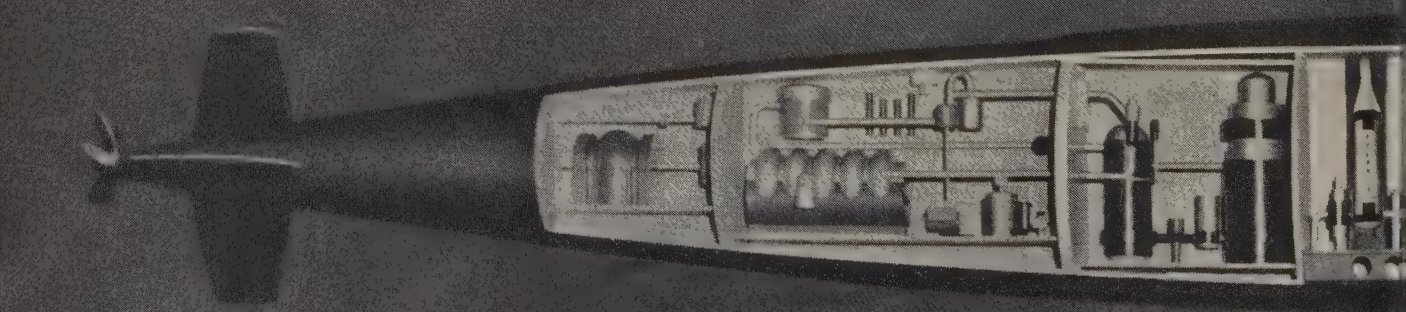


This refractory-free, high-tempera ture vacuum furnace for critical hea treating operates at temperatures up t 4200 deg F and is for use in labora tories or production work where vac uum operation is required. Parts c material up to 10 inches in diamete by 10 inches in height, weighing up t 50 lbs, can be processed, according t **General Electric Co., Industrial Heat ing Dept., Dept. S/A, Schenectady 5 N. Y.**

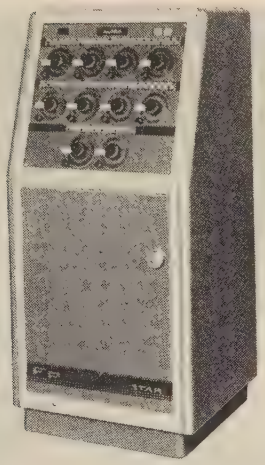
Heating space is 15 inches in di ameter by 16 inches high to provid temperature uniformity in the loa area.

Write in No. 425 on Reader Service Ca

Undersea launch pad for sixteen Pola



ALARM READOUT handles 100 points

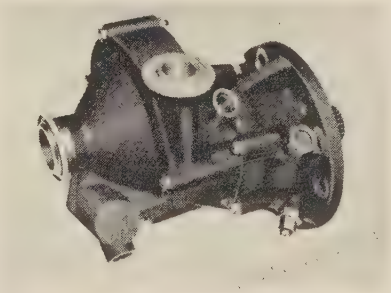


This temperature alarm readout simultaneously monitors up to 100 temperature points, depending upon the number of 10-unit panels it contains. When any one of the temperature points being sensed reaches the temperature indicated on its control dial, an alarm is sounded, and the critical point identified by a numbered light on the control panel, says **Fischer & Porter Co., Dept. S/A, 303 Jacksonville Road, Hatboro, Pa.** Constant contact is said to eliminate time lag.

As each channel operates independently, the unit will continue to sense the other 99 temperature points and will alarm under off-normal conditions.

Write in No. 426 on Reader Service Card

INJECTION PUMP operates 1500 hours

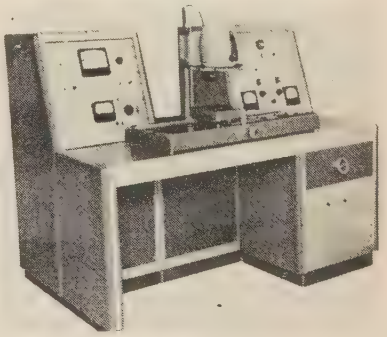


This water injection pump is built to operate for 1500 hours between overhauls. Primary factor in the high reliability and long life is said to be owing to elimination of contact seals and grease-packed bearings, according to **Sunstrand Aviation, Dept. S/A, Rockford, Ill.**

It can run almost indefinitely under dry conditions with a negligible rise in temperature.

Write in No. 427 on Reader Service Card

IR DETECTOR TESTER for production control



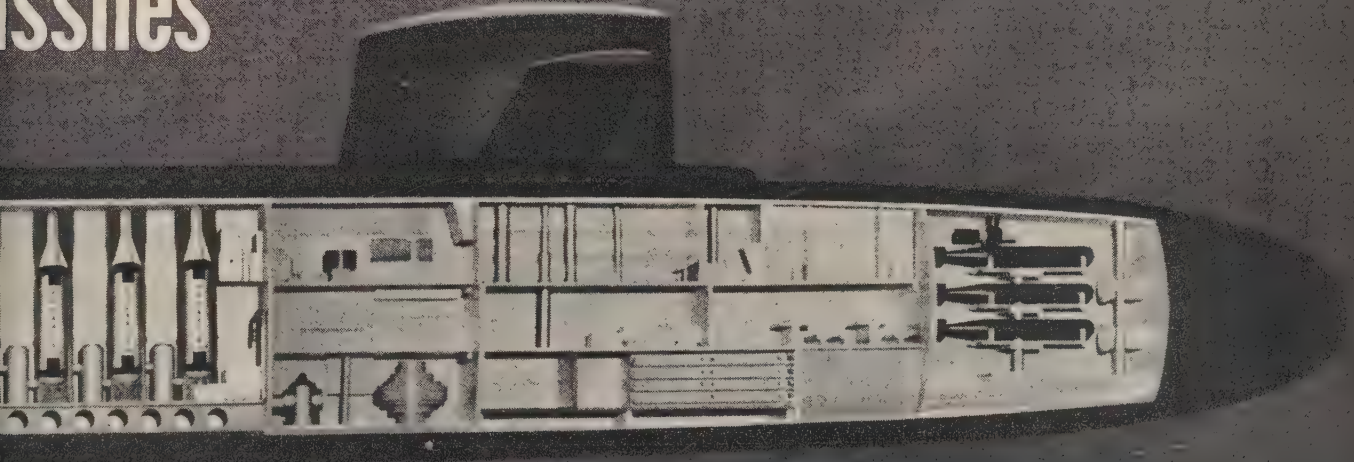
Model 301 Infrared Detector Test Console is a test package for use with photoconductors, photovoltaic detectors, bolometers and thermo-couples. The console is designed to check the characteristic of detectors at a rate of from 500 to 1000 units per day, says **Infrared Standards Lab., Dept. S/A, 10555 Magnolia Ave., Riverside, Calif.**

The tester may be modified for particular testing programs. Special features include footfeed detector indexing, direct-reading differential resistance bridge, and monochromatic responsivity measurement.

Write in No. 428 on Reader Service Card

more on next page

issiles



J. S. Navy Polaris submarine is a self-sufficient missile base. It provides comfortable quarters for its ndred-man crew and carries supplies for several months. In its launching tubes—eight on each side, as shown in this away model—will nest 16 Polaris missiles. But a Polaris sub differs from all other missile bases in one important pect: it can disappear from the face of the earth for weeks at a time. Though its position in ocean depths will be known, its presence will be felt. For—should America ever be attacked—each Polaris sub could launch its Polaris missiles in as many minutes. Lockheed is prime contractor and system manager for the Polaris missile.

LOCKHEED

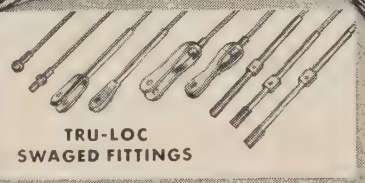
MISSILES & SPACE DIVISION
SUNNYVALE, CALIFORNIA

NEW "NO-MAG"

ACCO for Better Values

NON-MAGNETIC AIRCRAFT CABLES

- GOOD THERMAL CHARACTERISTICS
- CORROSION RESISTANT
- HIGH FATIGUE RESISTANCE
- HIGH ABRASION RESISTANCE
- PREFORMED CONSTRUCTION



TRU-LOC SWAGED FITTINGS

Eliminates Instrument Interference!

• Just as we expected, many aircraft designers were interested in the recent announcement of our new non-magnetic aircraft cable. If you did not see it, "NO-MAG" has these characteristics:

NON-MAGNETIC PROPERTIES . . . "NO-MAG" cable is made from type 305 stainless steel. It remains non-magnetic after severe cold working —in contrast to standard stainless steel aircraft cable which shows a pronounced increase in magnetism after swaging, wire drawing or similar operations.

This non-magnetic property of "NO-MAG" cable eliminates instrument interference from cable magnetism.

CORROSION RESISTANCE . . . New "NO-MAG" cables have corrosion-resistant qualities similar to, but slightly better than, cables made of standard stainless steel.

GOOD THERMAL CHARACTERISTICS... The thermal expansion characteristics of new "NO-MAG" cable are much closer than those of standard stainless steel or carbon steel cables to the characteristics of aluminum alloys used in aircraft. This greatly simplifies maintaining cable tension under various changes in temperature.

HIGH FATIGUE RESISTANCE . . . Preformed construction and careful processing give new "NO-MAG" cable high fatigue resistance.

HIGH ABRASION RESISTANCE . . . New "NO-MAG" cable shows greater abrasion resistance than standard stainless steel aircraft cables.

TENSILE STRENGTH, while lower than that of stainless and carbon steel, is sufficient to enable replacing these, size for size, with "NO-MAG" on many applications where the characteristics of "NO-MAG" are required.

USE WITH SWAGED TERMINALS . . . Swaged terminals can be applied to standard AN dimensions.

COMPLETE RANGE OF SIZES, CONSTRUCTIONS . . . New "NO-MAG" is furnished in sizes from 1/16" to 1" in all of the standard aircraft cable constructions.

Get the complete story on this new technical development for the aircraft industry. Write today to Detroit office.

Automotive and Aircraft Division
AMERICAN CHAIN & CABLE

ACCO TRADE MARK

601 Stephenson Bldg., Detroit 2

6800 East Acco Street, Los Angeles 22 • Bridgeport 2, Conn.

Write in No. 171 on Reader Service Card at start of Product Preview Section

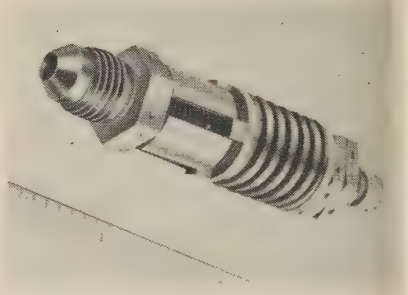
INTEGRATING GYRO is miniature

Model M2514-02, a miniature floated rate integrating gyro, is designed to be mounted directly on the frame of missiles or aircraft. The unit provides a linearity of 0.02 per cent and a large angular momentum of 250,000 gm-cm^2 per sec., says **Kearfott Co., Inc., Dept. S/A, 1500 Main Ave., Clifton, N.J.**

The gyro has a large angular input capability enabling it to be used in place of a stable platform in certain systems.

Write in No. 429 on Reader Service Card

HOT GAS VALVE for 2000-deg service



The Model 2200 relief valve, constructed entirely of stainless steel, has been designed for hot gas service up to 2000 deg F, says **Pyronetics, Dept. S/A, 11937 E. Slauson, Sante Fe Springs, Calif.** It exhibits a narrow pressure control band without drift in solid propellant gas generators.

Cracking pressure is adjustable from 1000 to 15,000 psi, hysteresis is under five per cent, and mass flow capability is over 0.015 lb/sec at 1000 psi. The two-oz valve has a poppet design that eliminates chatter.

Write in No. 430 on Reader Service Card

FUSED SILICA permits many shapes

These shapes, and many others, are made of a ceramic-like material known as multiform fused silica. It possesses thermal and electrical properties for flight vehicle applications. Silica in the gaseous state is condensed into a solid slab, according to **Corning Glass Works, Dept. S/A, Corning, N. Y.** It can withstand long-term use at temperatures above 1700 deg F and intermittent use to 2250 deg F. The softening point is 2880 deg F. Coefficient of thermal expansion is $3x10^{-7}$ per deg F.

The material can be machined to tolerances of ±.001 inches. Density is 1.9 to 2 grams per cubic centimeter, or 120 to 125 lbs per cubic foot. It has a porosity of 9 to 13.6 per cent.

Write in No. 431 on Reader Service Card

more on page 277

NEW DELCO 50-AMP. TRANSISTORS

HIGHER CURRENT THAN EVER BEFORE FOR MILITARY AND COMMERCIAL USE

	2N1518	2N1519	2N1520	2N1521	2N1522	2N1523
Maximum Collector Current (Amps.)	25	25	35	35	50	50
Maximum Collector to Base Volts, Emitter Open, Max Ico 4ma	50	80	50	80	50	80
Minimum Open Base Volts (1-Amp. Sweep Method)	40	60	40	60	40	60
Maximum Saturation Volts at Maximum Collector Current	0.7	0.7	0.6	0.6	0.5	0.5
Gain at Ic at 15 Amps.	15-40	15-40	17-35	17-35	22-45	22-45
Minimum Gain at Maximum Collector Current	12	12	12	12	12	12
Thermal Resistance Junction to Mounting Base (°C/Watt)	0.8	0.8	0.8	0.8	0.8	0.8

Characteristics at 25°C Maximum Junction Temperature 95°C

A new family of high current transistors featuring the 50-ampere 2N1522 and 2N1523. Two 25- and two 35-ampere types round out the line. All thoroughly tested and completely reliable. Available in production quantities. Call or write your nearest Delco Radio sales office for full product information and applications assistance.

DELCO RADIO
DEPENDABILITY
RELIABILITY

Division of General Motors
Kokomo, Indiana

Newark, New Jersey
1180 Raymond Boulevard
Tel: Mitchell 2-6165

Chicago, Illinois
5750 West 51st Street
Tel: Portsmouth 7-3500

Santa Monica, California
726 Santa Monica Boulevard
Tel: Exbrook 3-1465

Detroit, Michigan
57 Harper Avenue
Tel: TRinity 3-6560

Write in No. 172 on Reader Service Card

Write in No. 173 on Reader Service Card

LIQUIFLOW*: CAPACITY UNLIMITED, EFFICIENCY UNEQUALED

The Stewart-Warner Corporation relies on low-cost, flexible CO_2 for the rigid testing during development of fuel preheaters for SAC's Jet Bombers

Jet bombers for the Strategic Air Command—vital cogs in a vast program to assure safety and security for every American. The South Wind Division of the Stewart-Warner Corporation of Indianapolis, Indiana, tested fuel preheaters intended for SAC's jet bombers, simulating environmental conditions from ground level to 60,000 feet.

The logical choice of refrigerant for these tests: Liquiflow.

Stewart-Warner found this CO_2 system preferable to all others for four major reasons:

1. Lower initial investment—a mechanical unit of comparable output would be so large that the cost would be prohibitive.
2. Unlimited refrigeration capacity—Liquid Carbonic's permanent Liquiflow storage tank, local plant and supply trucks offer an abundance of liquid CO_2 whenever needed.
3. The unique design of the installation provides rapid pulldown, reduces engineering man-hours and manual labor with no breakdown worries . . . no maintenance.
4. Versatility—Stewart-Warner's environmenta program includes an altitude chamber, produc testing, temperature testing, and negative an positive pressure testing—all with the use o Liquiflow.

CO_2—ideal for "crash" programs

Stewart-Warner was given just one month to me the specifications for the tests; in that time, thanl to the combined efforts of Stewart-Warner ar Liquid Carbonic engineering teams, the installatio was designed, installed, and ready to go.

The Problem: Government specifications require that the fuel be prepared at 100° F., with maximu water saturation. Next, the temperature of the fu was to be lowered gradually to −70° F. over period of 13 to 14 hours. Water was to be inject periodically to assure ice crystals, and the fu sampled every 15 minutes for ice. Finally, the fu was to run through the heat exchanger at 250 2000 gallons per hour, and emerge at a temperatu range of 32° to 47° F.—with no ice.

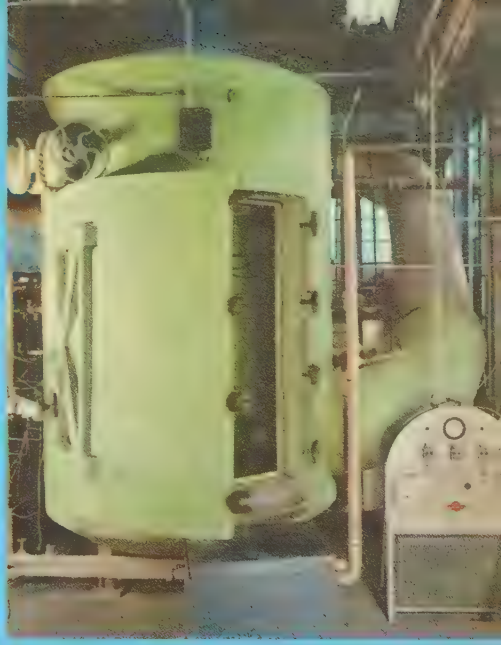
The solution: Stewart-Warner's first step was heat the 5000 gallons of fuel to 100° F.; next, f

*Liquiflow is Liquid Carbonic's registered trade-mark for liquid carbon dioxide systems.

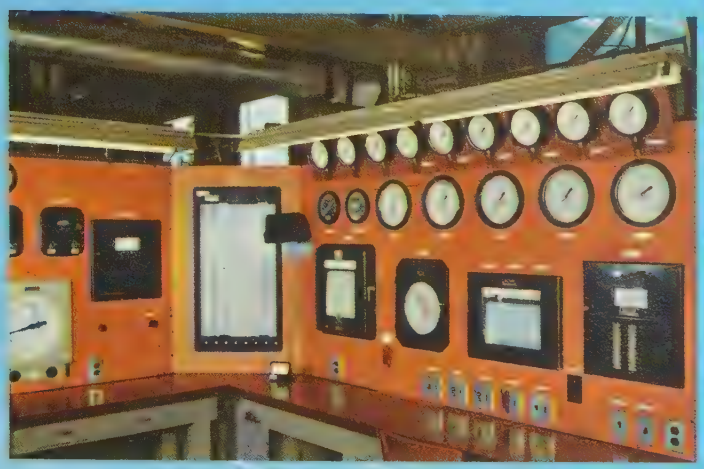
Testing site: Liquiflow inst lation at upper left; fuel tank upper right. Pipes transp Liquid CO_2, water and fuel testing tank.

Liquiflow installatio Stewart-Warner's assurance an always ample supply of c bon dioxide; rail car delive provides auxiliary supply.

Testing chamber: the site of all negative and positive pressure tests. Liquiflow tank in lower right for immediate supply.



Control headquarters: using this comprehensive control panel, Stewart-Warner carefully tracks the progress of all tests.



every 1000 gallons of fuel, six pints of water were to be added. The fuel was to settle for eight hours, after which the excess water was to be drained off.

A CO_2 snow tube was inserted in a sublimation tank containing 1000 gallons of alcohol. The alcohol then traveled to a fuel conditioning tank, gradually lowering the fuel temperature. The entire operation required from 17,500 to 18,500 pounds of CO_2.

In using Liquiflow—Stewart-Warner has increased efficiency, cut costs and simplified its operation, and was able to start on its qualification tests of equipment just one month after receipt of the specifications. If low-temperature environmental testing is in your present or future plans, let Liquid Carbonic's engineers work with you. One of Liquid Carbonic's many supply depots is near you to assure you of fast, efficient delivery. Call your Liquiflow representative today—he is trained to solve your problems!

Liquid Carbonic is a Major Producer of Compressed Gases: Oxygen, Acetylene, Nitrogen, Hydrogen, Argon, Carbon Dioxide, Nitrous Oxide, Helium and Various Gas Mixtures.

GENERAL DYNAMICS CORPORATION

Liquid Carbonic Division

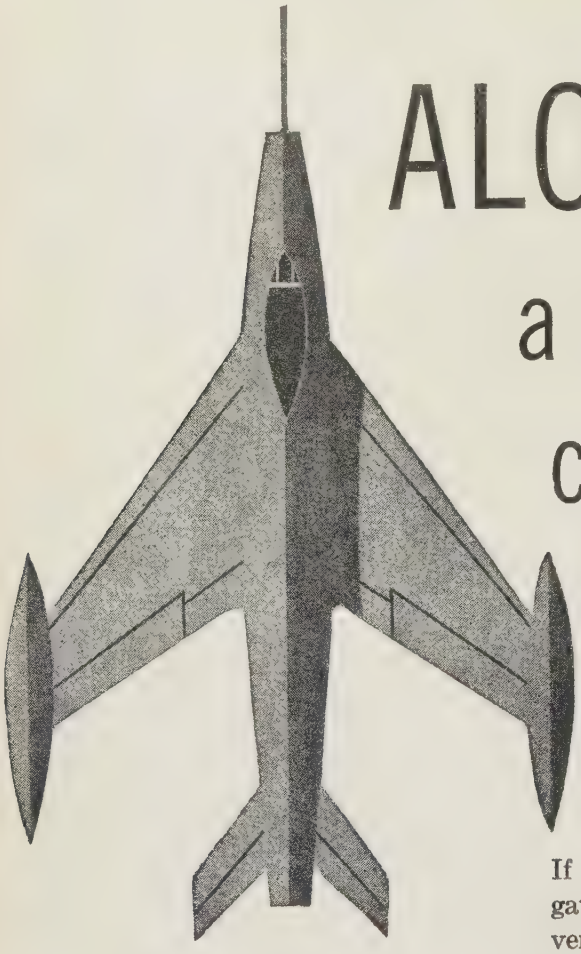
Dept. TE, 135 S. LaSalle Street

Chicago 3, Illinois

In Canada:

Liquid Carbonic Canadian Corporation, Ltd.,
Montreal 9, Quebec

Amchem points the way...



ALODINE 1200S

a new surface conversion treatment for aircraft aluminum!

If you are producing aluminum for aircraft fabrication, investigate the production advantages of Alodine 1200S—the new conversion coating that provides constant, uniform quality as well as big savings in time, equipment and processing costs!

Through increased chemical activity Alodine 1200S slashes processing time up to 50 percent! A 1200 system can be installed on your production line quickly and conveniently . . . and bath is maintained chemically . . . no special equipment required to control contamination. In an Alodine 1200S system, products can be processed through dip in the same time cycle other conversion coatings require for continuous spray lines. One processor is now using Alodine 1200S in a 45- to 60-second treating cycle compared with a former process which took six minutes—and he's doing it with no increase or revision in existing processing facilities!

Passed with flying colors!

The first major aircraft manufacturer has successfully completed rigorous testing procedures on Alodine 1200S and reports complete satisfaction of its many advantages in aircraft processing of aluminum. Write for details today!

Protect your aircraft aluminum fabrications best, at less cost, in less time with Alodine 1200S—qualified under Government Specification MIL-C-5541.

AMCHEM ALODINE 1200S

Amchem and Alodine are registered trademarks of AMCHEM PRODUCTS, INC. (Formerly American Chemical Paint Co.)

AMBLER, PA. • Detroit, Mich. • St. Joseph, Mo. • Niles, Calif. • Windsor, Ont.

Write in No. 174 on Reader Service Card at start of Product Preview Section

GATE VALVES for fluid service

This gate valve features mechanically loaded and retained teflon seals, advanced roller type clutches, and complete interchangeability of actuators. These off-the-shelf items depart from special order practice, says **Whittaker Controls, Dept. S/A, 915 No. Citrus Ave., Los Angeles, Calif.** They are adaptable to custom specifications.

The valves are of one-piece lightweight construction, and feature through-mounted rather than threaded holes, precluding thread damage.

Write in No. 449 on Reader Service Card

TAPE RECORDER is miniature

Model PS-300 two channel recorder is intended for applications where small space and low power consumption are major considerations. The recorder will operate at any tape speed up to 48 ips, by-directional, with end of tape sensing, says **Precision Instrument Co., Dept. S/A, San Carlos, California.**

The recorder nominally employs 4 in co-axially stacked reels which hold 900 ft of ½ mil tensilized Nylon tape, ¼ in wide. Frequency response is up to 160 Kc, ±3 db at 48 ips.

Write in No. 450 on Reader Service Card

SYNCHRONOUS MOTORS have high precision

A line of precision hysteresis synchronous electric motors that will withstand temperature ambients from −32 deg C to 135 deg C has been announced by **Hysyn Electromotive, 915 No. Citrus Ave., Dept. S/A, Los Angeles 38, Calif.**

The motor induced flutter will not exceed 0.1 rms at 1200 rpm or 0.15 rpm at 360 rpm while stray external magnetic field with a normally shielded head is held to −47 DBM.

Write in No. 451 on Reader-Service Card

more on next page

Check Employment Inquiry Form on Page 211 ➡

NEW DIMENSIONS TO SPACE AGE PROGRAMS BY LOCKHEED

Highly advanced infrared studies are but one of many challenging fields at Lockheed. Activities in infrared embrace research and development of advanced systems and subsystems for missile and aircraft detecting, tracking, ranging and eventually surveillance.

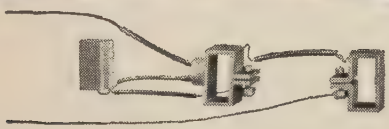
Some of the other programs that provide a fascinating challenge to creative engineers and scientists include: Solid state physics studies along several lines, including improved radiation sensors, new solid state electronic devices, and in support of other research, new and better conductive, insulating and structural materials for military and commercial use; underwater sound propagation and oceanography studies for anti-submarine warfare programs; solar radiation studies; the flight sciences; space psychophysics, biophysics and astrophysics studies concerned with human factor problems in space vehicle environments; supersonic and STOL vehicles for safe, fast, economical atmospheric and space travel.

Scientists and Engineers of outstanding ability are invited to explore the opportunities offered by a company that today is looking far into the future. Please address your inquiry to: Mr. E. W. Des Lauriers, Manager Professional Placement Staff, Dept. 1905, 2401 No. Hollywood Way, Burbank, California.

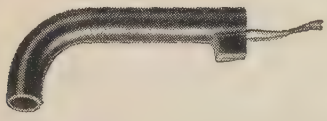
LOCKHEED

CALIFORNIA DIVISION

CHROMALOX
FLEXIBLE AND MOLDED
ELECTRIC HEATERS

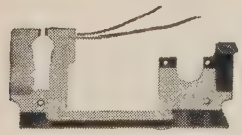


Electronic heating harness molded to fit small object. Three woven heaters molded in high temperature refractory and aluminum case (left) and glass and polyester resin (center and right). Small thermostat is molded to base of center heater.



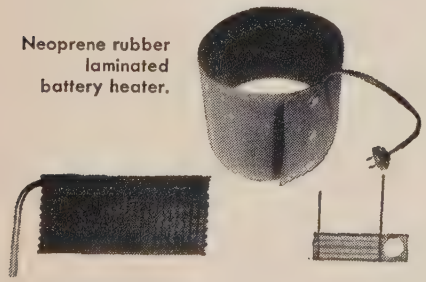
Neoprene rubber molded heater, eliminates ice clogging of aircraft pitot tube.

Silicone rubber laminated heater molded on a 2⅛″ spherical radius. Two of these completely cover and protect guided missile storage battery reservoir.



Silicone rubber laminated heater bonded to a metal component for an aeronautical camera.

Neoprene rubber laminated battery heater.



Woven heaters. Temperatures to 800°F. Any size or shape up to 24″ wide and to any length. Can be supplied with eyelets, snap fasteners, mounting holes. Moisture and abrasion resistance can be provided by silicone rubber coating.

Chromalox Flexible and Molded Heaters are shaped-to-fit to put exact amounts of heat where it is needed.

FREE—Send today for new Bulletin J-1003 which gives detailed engineering information. Or, call your Chromalox Representative for personal assistance with any heating problem. 91812

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Electric Heat
INDUSTRIAL • COMMERCIAL • RESIDENTIAL
EDWIN L. WIEGAND COMPANY
7500 THOMAS BLVD., PITTSBURGH 8, PA.

Write in No. 175 on Reader Service Card

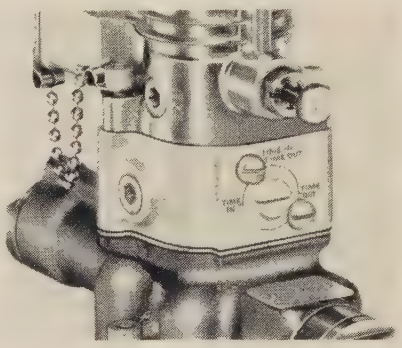
TELEMETERING OSCILLATOR is transistorized

This millivolt oscillator is small and lightweight and draws less power than conventional oscillators. The most important feature is its low-level input which eliminates the necessity of separate dc amplifiers, says **Hoover Electronics Co., Dept. S/A, 110 W. Timonium Road, Timonium, Md.**

The unit has an internal voltage regulator. Power requirement is +26 V. The oscillator is produced to IRIG specifications of frequencies and deviations for channels 5 through 18 and A through E.

Write in No. 452 on Reader Service Card

TIMING SEQUENCE HEAD for 0-30 seconds delay



This universal timing sequence head eliminates timers and relays in circuits requiring time delay in valve function —from 0 to 30 seconds. This can be extended up to several minutes by connecting an accessory reservoir, according to **Valvair Corp., Dept. S/A, 454 Morgan Ave., Akron 11, Ohio.** Valve function can be changed in seconds without disassembly and with line pressure on the unit.

Two types include one for direct mounting between the pilot and valve body; the other for direct mounting on the valve body, but with remote pilot control.

Write in No. 453 on Reader Service Card

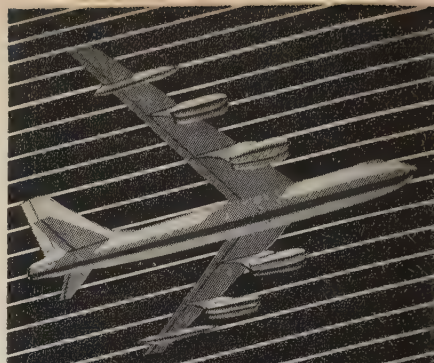
BI-PROPELLANT VALVE for fuel, oxidizer lines

This normally-closed, explosive-actuated valve is for simultaneous opening of fuel and oxidizer lines. Materials are selected for use with UDMH and RFNA. It is designed for manifold mounting; weight, 8 ozs. Minimum flow passage for either fuel or oxidizer line is 0.25 inch diameter; valve provides zero leakage prior to firing, says **Pyronetics, Dept. S/A, 11973 E. Slauson, Santa Fe Springs, Calif.**

It is initiated by 1 amp or more applied for 20 milliseconds; bridgewire resistance is one ohm. Suitable for fluid pressures from zero to 1500 psi.

Write in No. 454 on Reader Service Card

more on page 282

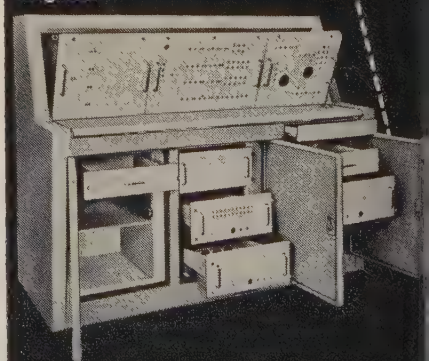


Protect Your Center of Guidance

For these vital centers of control and guidance complete protection of their sensitive instruments is of primary importance.

The Falstrom Company has been specializing for many years in the design and fabrication of control and mapper consoles, rack cabinets, control benches, chassis and all kinds of housings, for prototypes or production, in all metals.

Write for information or phone PRescott 7-0013 for a Falstrom Field Sales Engineer.



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FALSTROM COMPANY
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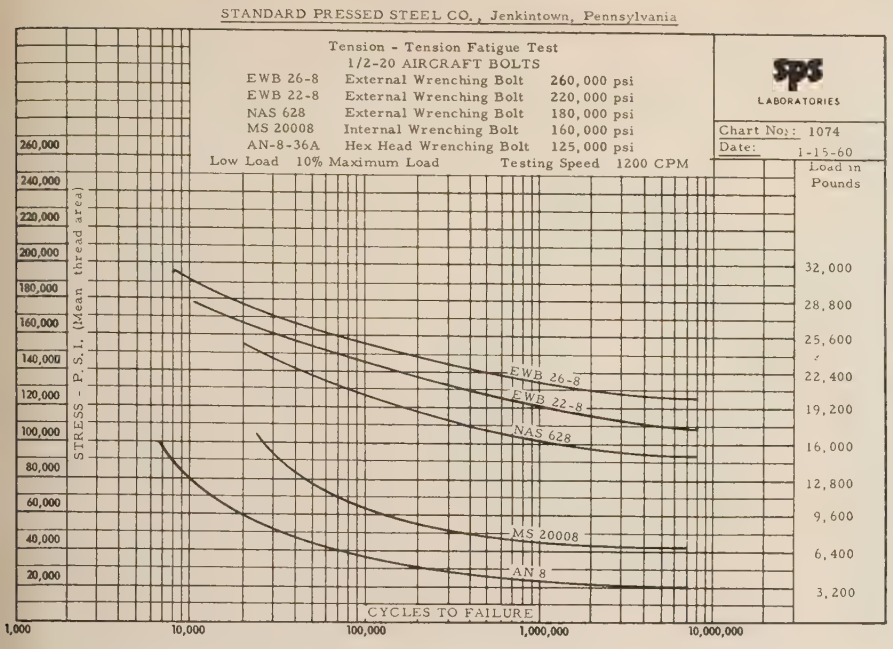
Write in No. 256 on Reader Service Card

What is the *one* sure way to determine fatigue strength?



The problem of fatigue life in high-strength bolts is complex, challenging . . . and critical. Certainly the success of aerospace projects often hinges on whether bolts hold. That's why we feel that a clearer insight into fatigue on the part of all involved in specifying fasteners is extremely important.

Tensile load fluctuates

In most applications the tensile load on a bolt does not remain static. It fluctuates because of the operation of the mechanism. These changing loads can cause fatigue fractures in the bolt. To illustrate: if a *constant* load of 14,000 lb. is applied to a fastener with an ultimate strength of, say, 28,000 lb., it will hold indefinitely without failure. However, if the same load is *applied and removed many times*, the part will eventually fail due to fatigue.

Destructive testing

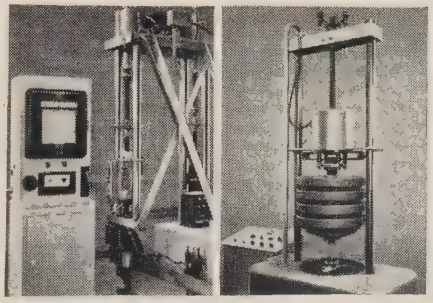
Destructive testing is the *only* sure way to determine fatigue characteristics. The bolt must be broken. Then we know its fatigue properties.

This testing must be ceaseless . . . ruthless . . . an integral part of the production process. We must destroy enough of *each* lot so that we can be assured of the fatigue strength of the others. Here at SPS in a lot of 100 high-strength aircraft bolts we fatigue-test five to destruction (in addition to destructive testing for tensile and shear strengths). If these five measure up, we are confident that the other 95 are highly reliable.

Testing equipment

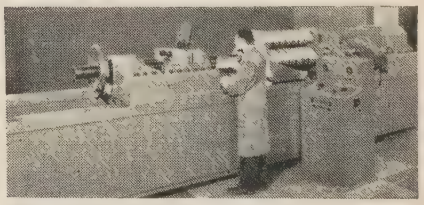
Mention of just some of the equipment in the SPS laboratories for advanced fastener research should give you some idea of the many complex and powerful machines required.

We operate twelve Krouse direct stress fatigue machines—3000, 5000, 15,000 and 60,000 lb. Loads are controlled by electrical resistant strain gages and other electronic equipment, such as oscillographs. To insure accurate results, we calibrate them with proving rings certified by the National Bureau of Standards.



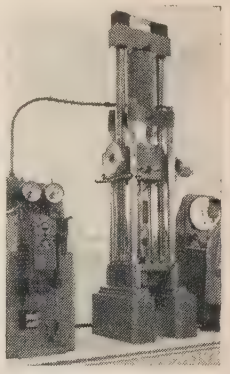
Krouse Amsler

To obtain answers in less time, we use several Amsler fatigue machines like the one shown at bottom of column 2. By cross-checking the results obtained on one testing machine against those from another, or several others if necessary, we can be certain of the accuracy of our findings.



Schenck

For fatigue testing large-diameter fasteners, we operate a 145,000 lb. Schenck machine, one of two in the U.S. used for certifying bolts (the other serves the Air Force), and a 250,000 lb. Amsler—largest fatigue machine in this country used exclusively for fasteners . . . with capabilities beyond present day utilization, in anticipation of strength-to-weight ratios yet to come.



Amsler—250,000 lb.

Implications

High-strength fasteners with reliable fatigue life can be produced only by a manufacturer with a complete test facility. A user of these bolts lacking the equipment to test them should not be buying them from a manufacturer who also cannot certify their fatigue strength.

So we say evaluate your source of supply very, very carefully. Can he honestly—and authoritatively—assure you that his bolts will not fail from fatigue?

AIRCRAFT / MISSILE Division

JENKINTOWN 54, PENNSYLVANIA
SANTA ANA, CALIF.

SPS

where reliability replaces probability

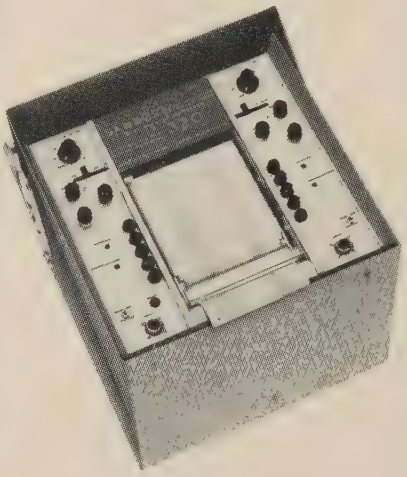
Reprints of this message are available upon request.

Write in No. 176 on Reader Service Card at start of Product Preview Section

keep an accurate graphic record

OF RESEARCH, DESIGN, TEST DATA

two channels



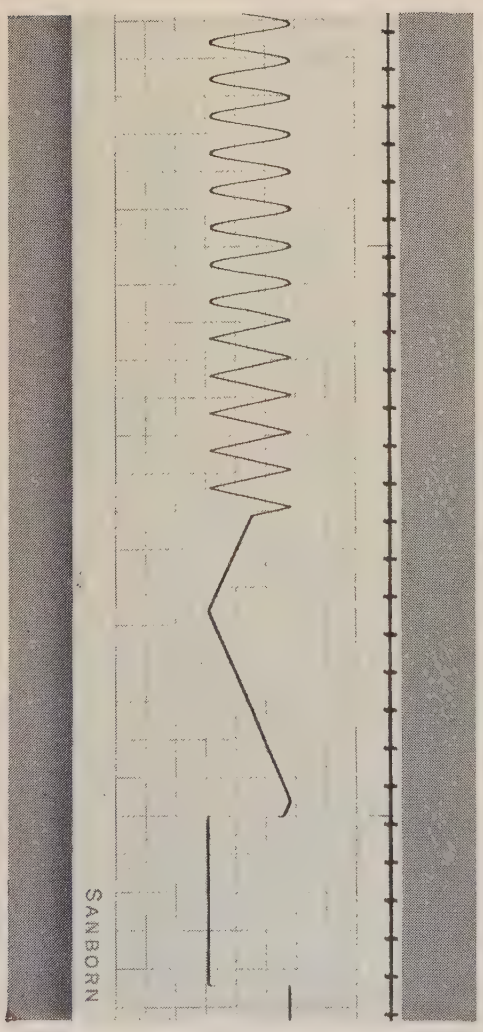
For General Purpose DC Recording — Model 320

For recording *two variables* simultaneously, the Model 320 provides a versatile, transistorized amplifier for each input signal. The rugged 2-channel recorder assembly has heated stylus recording on two *50 mm wide* rectangular coordinate channels, 4 pushbutton chart speeds, and 6 inches of visible chart. The Recorder can be placed vertically, horizontally or at a 20° angle.

MODEL 320 SPECIFICATIONS

Sensitivity: 0.5, 1, 2, 5, 10, 20 mv/mm and v/cm
Frequency Response: 3 db down at 125 cps, 10 mm peak-to-peak
Common Mode Voltage: ±500 volts max.
Common Mode Rejection: 140 db min. DC
Calibration: 10 mv internal ±1%
Output Connectors for each channel accept external monitoring 'scope or meter
Price: $1495

NEW SANBORN PORTABLE DIRECT WRITING RECORDERS FOR IN-PLANT, LABORATORY OR FIELD RECORDING



Two models of this 21 lb. brief case size recorder are available — Model 301 for AC strain gage recording, Model 299 for general purpose DC recording. Both provide immediately visible, inkless traces by heated stylus on 40 division rectangular coordinate charts . . . frequency response to 100 cps . . . 5 and 50 mm/sec chart speeds . . . approx. 4 inches of record visible in top panel window.

single channel

MODEL 301 SPECIFICATIONS

The amplifier section of the Model 301 is an all-transistorized carrier type with phase sensitive demodulator. The power supply and internal oscillator circuits are also transistorized.
Sensitivity: 10 uv rms/div (from transducer)
Attenuator Ratios: 2, 5, 10, 20, 50, 100, 200
Carrier Frequency: 2400 cps internal
Transducer Impedance: 100 ohms min.
Calibration: 40 uv/volt of excitation
Output Connector: for external monitoring 'scope or meter
Price: $750

MODEL 299 SPECIFICATIONS

Combines the dependability of transistors with the high input impedance of vacuum tubes for reliable broad-band DC recording.
Sensitivity: 10, 20, 50, 100, 200, 500 mv/div and 1, 2, 5 and 10 v/div
Input Resistance: 5 megohms balanced each side to ground
Common Mode Voltage: ±2.5 volts max. at 10 mv/div sensitivity increasing to ±500 volts max. at other sensitivities
Common Mode Rejection: 50:1 most sensitive range
Calibration: 0.2 volt internal ±1%
Output Connector: for external monitoring 'scope or meter
Price: Model 299 (with zero suppression) $700
Model 299A (without zero suppression) $650

All prices are F. O. B. Waltham, Mass., within continental U. S. A. and are subject to change without notice.

Contact your Sanborn Sales-Engineering representative for complete information, or write the main office in Waltham. Sales-Engineering representatives are located in principal cities throughout the United States, Canada and foreign countries.

SANBORN COMPANY

INDUSTRIAL DIVISION 175 Wyman Street, Waltham 54, Mass.

Write in No. 177 on Reader Service Card at start of Product Preview Section

VICKERS ECM COOLING SYSTEM plus

3M's FC-75 dissipates 47 kw input in 74 lb package

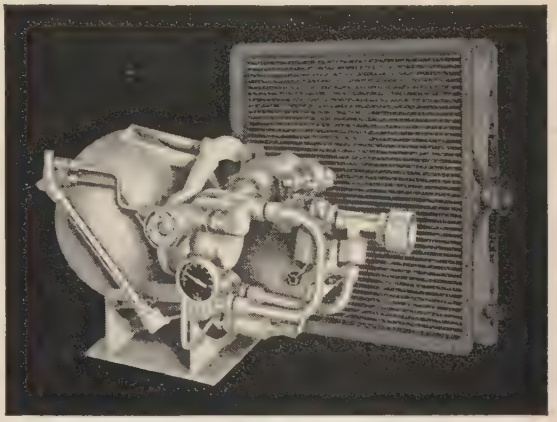
Vickers' 38 years of specializing in handling of fluids has been directed to "application-tailored" airborne cooling systems . . . reliable systems that are light weight and feature a broad range of flow and pressure characteristics.

This typical Vickers system circulates Minnesota Mining and Manufacturing Co.'s heat dissipating dielectric coolant, FC-75, through Sperry's advanced design electronic countermeasures system.

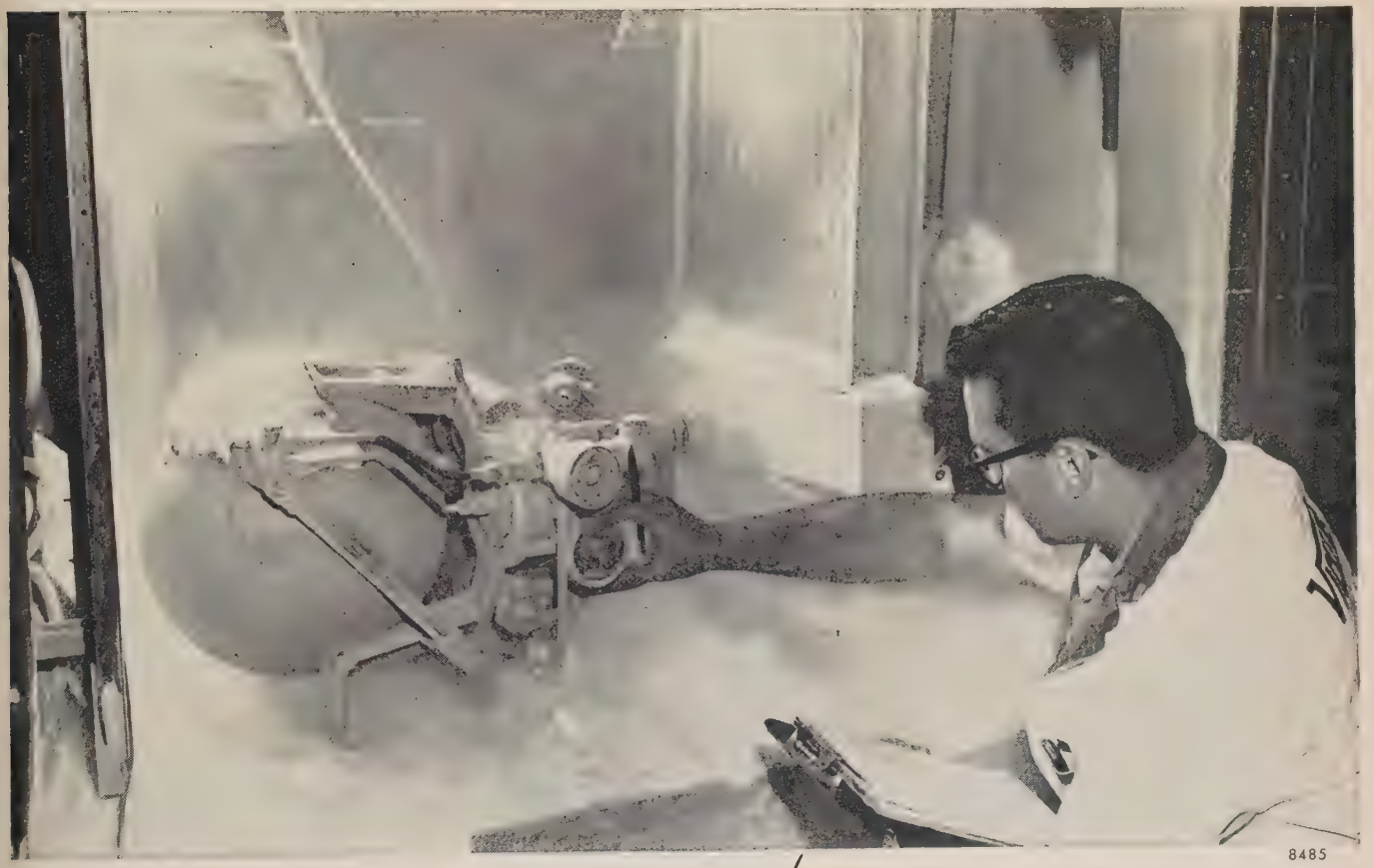
Heart of the Vickers cooling system is a single-stage, centrifugal pump that generates relatively low pressure and moves fluids at high flow rates. Because it is inherently simple in design, the Vickers pump offers high reliability and simplifies maintenance. Bearing design permits operation with fluids having low viscosities, in this instance FC-75, a fluordinated hydrocarbon.

Included in this package are safety interlocking devices for the protection of the pumping unit and ECM system. Maximum operating efficiency is assured even under unusually severe operating requirements. Such assurance stems from Vickers proven skills developed by long experience in designing and building components and systems for handling all types of fluid.

Write for Bulletin A-5244 for more details.



PUMPING UNIT AND CORE. Large airborne cooling system developed by Vickers' Aero Hydraulic Products division makes efficient use of 3M's FC-75 dielectric coolant to dissipate heat from electronic countermeasures equipment. Output pressure is required to be approximately 100 psi with fluid flow rates as high as 52 gpm. Operating range is from —65°F to 210°F. Pumping unit weighs 54 lb. dry and the heat exchanger core only an additional 20 lb. Shown below is part of the extensive testing program conducted by Vickers to prove out the new design. It included extremes of heat and cold as well as vibration, shock, attitude and other physical tests.



8485

AERO HYDRAULICS DIVISION
VICKERS INCORPORATED
DETROIT 32, MICHIGAN

division of
SPERRY RAND CORPORATION

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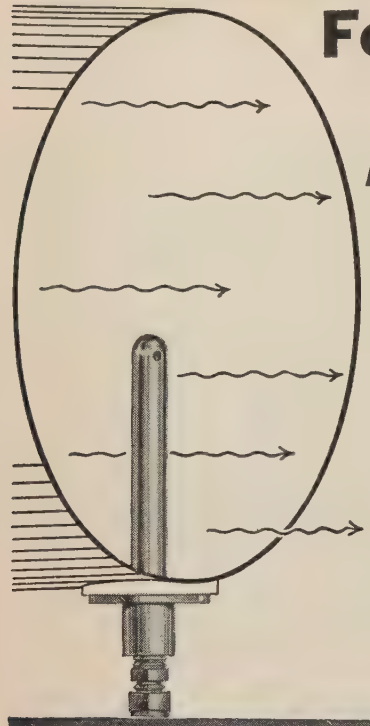
Non-Cooled Thermocouple For High Velocity Gas Streams



At Temperatures Up To 3600°F.

This new thermocouple can be used without water or air cooling in the high velocity gas streams of jet engine afterburners and ramjet and rocket exhausts. It includes a cermet radiation shield and support tube. Conduction errors from cooling are eliminated and installation is simplified. Radiation losses are reduced about 60%. In a typical application this probe endured temperature cycling from 1500 to 3000°F. at a 1500 ft./sec. velocity for 20 hours with no failure. Temperature changes of 2000°F./sec. have created no adverse effects. Conductors used are Platinum 30% Rhodium/Platinum 6% Rhodium to 3000°F., and Iridium Rhodium/Iridium to 3600°F. Contact Thermo Electric for adaptation of this thermocouple to your needs.

Write For EDS-36-2

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada:
THERMO ELECTRIC (Canada) LTD.,
Brampton, Ont.

Write in No. 179 on Reader Service Card at start of Product Preview Section
Please refer to page 90 for other Thermo-Electric ad.

Ask for Special Help When Brazing Stainless

Ask us for help in deciding how to best braze your stainless alloy assemblies. We successfully braze almost every known stainless steel, superalloy, and aluminum or titanium bearing metal.

Ask us to choose the best brazing alloy from the massive array of copper, silver, and nickel base alloys available. We know and use them all.

Ask us for a quotation on doing your stainless brazing or heat processing. Our pencils are sharp and so are the four furnace plants we operate to serve you.

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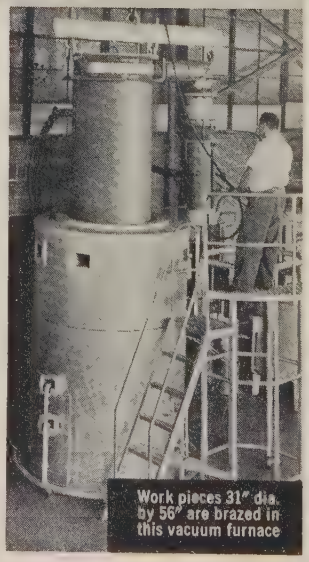
Stainless Processing Division
19345 John R Street • Detroit 3, Michigan
Wall Colmonoy furnace plants are maintained in Michigan, Pennsylvania, Ohio, and California



Write in No. 180 on Reader Service Card at start of Product Preview Section

VOLTAGE REGULATORS are transistorized

Highly regulated dc from unregulated dc sources is obtained by using a compact transistorized Voltage Regulator. Output voltages ranging from 6 to 35 Vdc are available from inputs ranging from 24 to 45 Vdc, says **Valor Instruments, Inc., Dept. S/A, 13214 Crenshaw Blvd., Gardenia, Calif.**

Line regulation is ±0.1 per cent of 10 mv whichever is greater. Output impedance is 0.10 ohm maximum. The unit measures 3x3x3 in. and weighs 16 oz.

Write in No. 455 on Reader Service Card

AMPLIFIER has all-transistor circuits

The CV-HZA high input impedance amplifier, a transistorized unit, handles high voltages and simultaneously provides a very high input impedance, says **Adage, Inc., Dept. S/A, 292 Main St., Cambridge 42, Mass.** The unit is expected to solve many circuit loading problems in analog computers, automatic test systems, potentiometer measuring equipment, and others.

Used as an isolation amplifier, the unit permits precise voltage measurements without disturbing the signal source, and errors due to circuit loading are eliminated. The CV-HZA has a full-scale signal swing of over ±100 V, and impedance runs into thousands of megohms. Other specifications include: long-term dc voltage stability; long-term voltage drift of ±300 uv; voltage gain of 1.0000; and output current up to two mg. Also available is the CV-HZA10, a model rated for plus or minus ten V. The CV-HZA is assembled on a 5 x 8-in. plug-in printed circuit card.

Write in No. 456 on Reader Service Card

SMALL MOTOR for continuous duty

The Model 38BG3, a miniaturized 1½-hp motor with an output shaft speed of 4600 rpm, has a diameter of three in. It is designed for use on a centrifugal blower, according to **Western Gear Corp., Dept. S/A, 132 W. Colorado Blvd., Pasadena, Calif.**

The ten-pole, 200-V, 400-cycle motor is capable of continuous duty operation.

Write in No. 457 on Reader Service Card

more on page 284

ANALOGUE
Data Handling Systems
DIGITAL

The DIDAS transmitter

891362	108572
243895	925841
239810	189463
654958	194857
193847	237583
901205	867493
294736	910485
271057	839120
984752	856321
379824	658493
105447	539582
459233	937562
811278	423038
532485	902475
114857	521054
984735	284731
927411	883746
210473	937561
567482	109235
665820	991375
857395	274837
948573	198573
195847	958473
248571	984421
125434	103425
354321	978679
748275	213486
859483	210084
942106	330198
772689	921006

DIDAS receiving and recording in laboratory conditions

- **Fully Transistorized**
- **Extremely High Speed**
- **Compact**
- **Reliable**
- **Modern Construction**
- **Rugged but light**

Speedy measurement and analysis of data has become a necessity in modern industry.
Armstrong Whitworth Aircraft have developed data handling systems for measurement and remote control.
The data can be transmitted at the speed of light by radio, or by cable link, with extreme accuracy.
In one system (the DIDAS vehicle system), over 250,000 different readings can be obtained in one minute. Analogue/digital and ditigal analogue converters, working at over 50,000 conversions a second, eliminate processing bottlenecks. Systems can be engineered to customers' requirements.

ARMSTRONG WHITWORTH AIRCRAFT LIMITED, Baginton, Coventry, England
(A member of Hawker Siddeley Aviation)

Write in No. 181 on Reader Service Card at start of Product Preview Section

Now 2 to 3 week delivery on popular BUORD* items...

and in production quantities!

Mark 7 Mod 0.....Size 15 Servo Motor
Mark 7 Mod 1.....Size 15 Servo Motor
Mark 12 Mod 0.....Size 15 Motor Generator
Mark 12 Mod 1.....Size 15 Motor Generator
Mark 16 Mod 1.....Size 18 Motor Generator
Mark 16 Mod 3.....Size 18 Motor Generator
(For transistor circuits)

The addition of our second factory means delivery in six to twelve weeks on many other G-M Servo Motors and Motor Generators as well; sizes 8 to 18, including other BuOrd items.

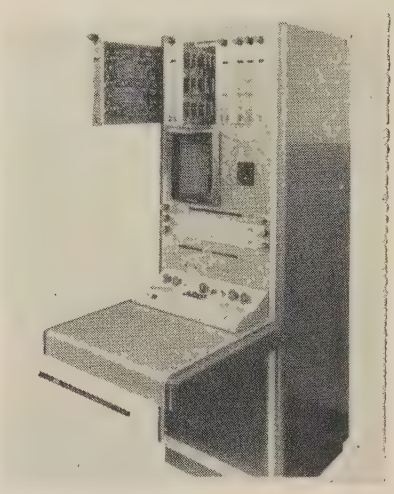
*Now Bureau of Naval Weapons

Ask also for full information; G-M Recommended Specification No. 665 and Catalog.

GM
G-M Servo Motors
manufactured by the Components Division of
G-M LABORATORIES INC.
4306 N. Knox Avenue • Chicago 41

Write in No. 182 on Reader Service Card

ANALOG EQUIPMENT for high speed computation



TRICE (Transistorized Realtime Incremental Computer Expandable) directly replaces analog computers for simulation and other purposes. As a part of an operational system, it can perform as a missile impact predictor, a process control optimizer, a satellite tracking computer, and for similar high speed computations, says **Packard Bell Electronics Corp., Technical Products Div., Dept. S/A, 12333 W. Olympic Blvd., Los Angeles, Calif.**

Developed as an outgrowth of TRICE techniques, DAFT (Digital-Analog Function Table) provides accurate and repeatable arbitrary function generation for analog computers, and for Trice. The digital outputs of DAFT are compatable with the input requirements of TRICE while TRICE variables can be employed directly as DAFT independent variables.

Write in No. 458 on Reader Service Card

VIBRATION CHAMBER for environmental test

An acoustic vibration chamber, capable of demolishing missile components is specially designed for environmental testing application in which vibration testing is combined with high and low temperatures and extreme altitude simulation. It is sealed and allows pumping of the shaker to extreme altitudes without contamination of the pumping system by constant leakage, and also allows use of "piggy-back" altitude or temperature chambers for component testing, says **Ling Electronics, Inc., Dept. S/A, 9937 W. Jefferson Blvd., Culver City, Calif.** This technique of liquid cooling is said to allow improved dynamic response of electro-dynamic shakers.

Electrical coils are designed to prevent corona discharges under high altitude conditions. They range in size from 1,500 to 30,000 lbs of vibration output force for testing a small component.

Write in No. 459 on Reader Service Card

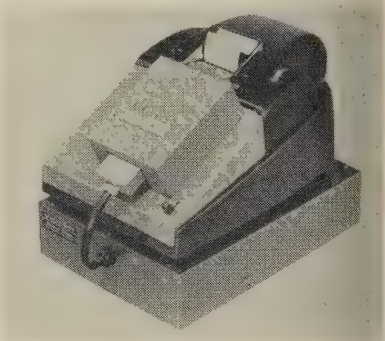
YIG SPHERES & DISCS are highly polished

Highly polished YIG spheres 0.020 ±0.002 in. which have a ferrimagnetic resonance linewidth of 0.65 ±0.25 oersteds, may be used in power limiters, harmonic generators, cavity-tuned filters and other microwave devices. Also available are highly polished YIG discs, free of inclusions, says **Microwave Chemicals Lab., Inc., Dept. S/A, 282 7th Ave, New York 1, N.Y.**

The discs can be oriented by X-rays if desired. Final polishing is performed using Linde A aluminum oxide.

Write in No. 460 on Reader Service Card

PRINTER may be modified



The Digit-Matic Scanning Printer scans and prints numbers stored in glow counter tubes, digital ohmmeters, Nixie display counters, or other electronic devices. The normal operating speed is 0.25 sec per column scanned, says **Victor Adding Machine Co., Dept. S/A, 3900 N. Rockwell St., Chicago 18, Ill.**

An additional 0.27 sec is added with non-totalizing printers and 0.35 sec with totalizing models. Operating on a minimum of +10V dc, input signal, the unit may be modified to include special numerical, alphabetical and other symbols for identification purposes.

Write in No. 461 on Reader Service Card

MICROWAVE SWITCH uses electron beam

The Beacotron is essentially a microwave energy coupler employing an electron beam for the coupling medium. Up to 60 db isolation between input and output can be readily obtained merely by adjusting the potential on a switch electrode, says **Tucor, Inc., Dept. S/A, 18 Marshall St., So. Norwalk, Conn.**

With the beam adjusted for full coupling, gain slightly greater than unity is possible. Various designs are now available for application at frequencies ranging from VHF through the 10,000 mc band.

Write in No. 462 on Reader Service Card

more on page 287

At 00h00m01s GMT, May 1, 1960, Martin logged its 523,692,000th mile of space flight

keep the lonely vigil . . . *Martin PM-1 air-portable nuclear*
ctor, to supply electricity and heat at remote Air Force stations,
ow being developed and produced for the AEC.

MARTIN

NIKE HERCULES

With deadly accuracy the U.S. Army's new Nike Hercules ground-to-ai guided missile streaks out to meet an approaching enemy air force. It nuclear warhead can wipe out an entire formation.

Western Electric selected Teflon* insulated wire for use in building th alert guidance and control systems of this faster, higher climbing Nik

As leading specialists in high temperature insulated wires and cables, th men and women at Hitemp are proud of this choice, and the role Teflo wiring plays in giving America a strong new perimeter of defense.

HITEMP WIRES, INC.

1200 SHAMES DRIVE, WESTBURY, NEW YORK

*Du Pont's trade name for Tetrafluoroethylene

Write in No. 183 on Reader Service Card at start of Product Preview Section

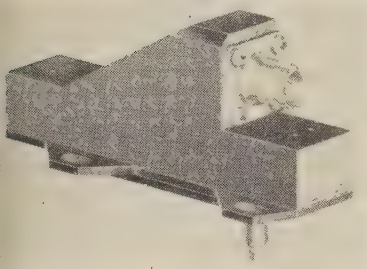
SIMPLIFIED COMPUTER for Doppler navigation

Simplified Computer 5452, conforming to Arino characteristic 543, will enable pilots to maintain track accurately and know the remaining distance to run to turning points or destinations, says **Marconi's Wireless Telegraph Co., Ltd., Dept. S/A, Christopher Martin Rd., Chelmsford, Essex, England.**

The computer will also operate with any Doppler sensor produced in accordance with Arinc characteristic 540.

Write in No. 260 on Reader Service Card

POTENTIOMETERS are side-actuated



Types 3063 and 3064 potentiometers offer stroke lengths of 1.89 in and 2.85 in respectively. Both types are extremely suitable for control surface feedbacks on missiles because of their long life and low noise characteristics, says **Markite Products Corp., Dept. S/A, 155 Waverly Pl. New York 14, N.Y.**

Features include high resistance to shock, acceleration and vibration in excess of 50 g's, and virtually infinite resolution and independent linearity better than ±0.5 per cent.

Write in No. 261 on Reader Service Card

SERVO VALVE is very reliable

A one-lb titanium electrohydraulic servo valve with only two moving parts has been designed for extreme reliability under the most severe environments in high-performance hydraulic systems, says **Kearfott Co., Inc., Dept. S/A, 1500 Main Ave., Clifton, N.J.** The hydromechanical feedback system the 6104 employs, substantially reduces flow force reactions and accomplishes hydraulic centering of pilot position without spring hysteresis and null shift.

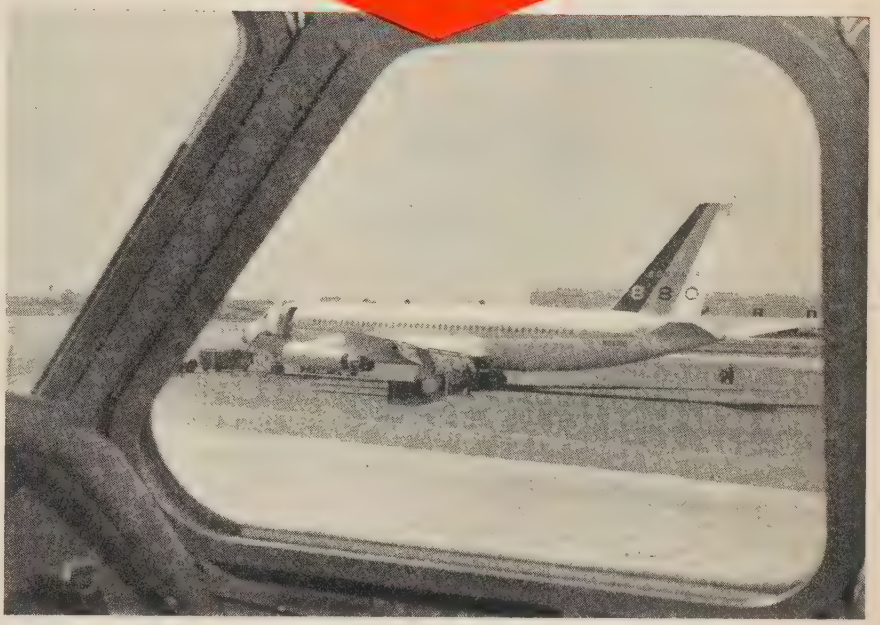
The two-stage, four-way flow control valve has a torque motor and amplifier in the first stage and a spool and sleeve arrangement in the second, or control, stage. Flow ratings range to 18.0 gpm at 3000 psi valve pressure drop, supply pressure 300 to 4000 psi, and proof pressure 6000 psi for the pressure port and 000 psi for the return port. The standard unit is useful over a —65 to 275 deg F range.

Write in No. 262 on Reader Service Card

more on next page

SUPERIOR | ACCURACY

in heat controls for jet windshields



Convair 880 jet airliners are first to use new, advanced design anti-fogging, anti-icing heat control systems developed by Magnetic Controls Company.

Windshield icing and fogging problems are considerably more complex for jet airliners, compared with those encountered by piston engine planes. With jet travel, faster speeds, higher altitudes, plus greater extremes in temperatures and atmospheric pressures, many new problems develop. Magnetic Controls proportional heat control systems have helped to solve these problems for Convair 880 jets. The Magnetic Controls systems offer four distinct advantages:

- **Automatic compensation for windshield aging.**
- **Ultra-reliable, fully static design.**
- **Elimination of thermal shock for longer windshield life.**
- **Superior accuracy — proportional plus integral control.**

For complete information about this system and how it may help you obtain precise, accurate heat control for many applications, write or phone Magnetic Controls Company today.

MAGNETIC CONTROLS COMPANY

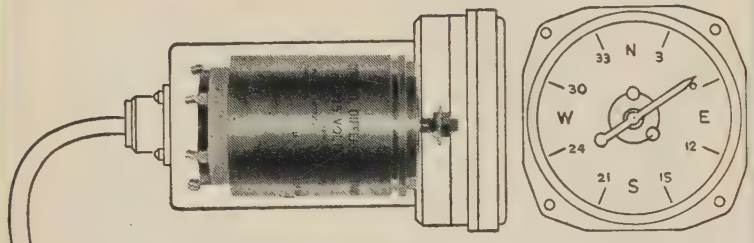
6409 CAMBRIDGE STREET • MINNEAPOLIS 26, MINN. • WEst 9-4691

Heat Control Systems • Static Inverters • Voltage Monitoring Systems

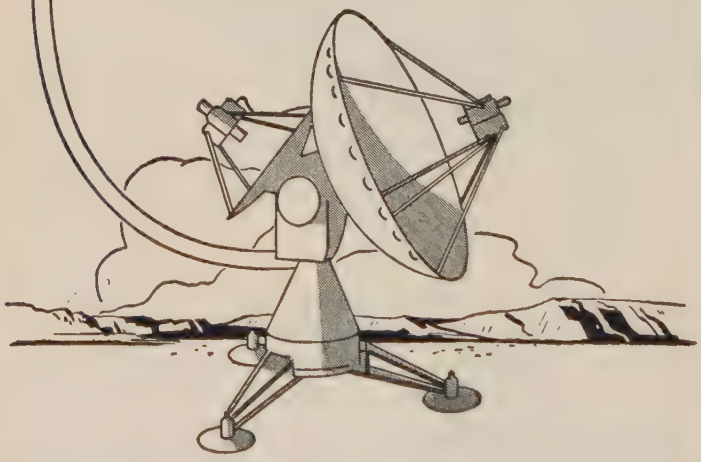
Write in No. 184 on Reader Service Card at start of Product Preview Section

Montrose DIVISION | Bendix AVIATION CORPORATION

60-CYCLE SYNCHRO INDICATOR



Now available a 23TR6a Synchro Receiver conveniently packaged for immediate installation in ground support equipment consoles or shipboard installations. Your choice of dial presentations which will accurately display the angular or position information received from a remote synchro transmitter. The receiver is ready for front or rear mounting in a $3\frac{9}{64}$" panel cutout with four .144 holes equally spaced on 3.5 diameter. The receptacle provided on the receiver mates with an AN3106-14S-2S plug. Power requirements are 115 volt, 60 cycle using 5 watts. The receiver is pressure sealed by "O" rings for protection against sand, dust and moisture. The synchro contained in this indicator meets the requirements of MIL-S-20708.



West Coast Sales and Service Office—117 East Providencia Avenue, Burbank, California
Canadian Sales Office—Aviation Electric Limited, 200 Laurentien Blvd., Montreal, Quebec, Canada
Export Sales and Service—Bendix International, 205 East 42nd St., New York 17, New York

Montrose Division
SOUTH MONTROSE, PA.

Bendix AVIATION CORPORATION

Write in No. 185 on Reader Service Card at start of Product Preview Section

FUEL NOZZLE
permits remote disconnect

A flow rate of 3000 gpm and a maximum pressure drop of 22 psi are available in this nozzle and fill valve for loading fuel, liquid oxygen or cryogenic fluid aboard aircraft and missiles, says **Parker Aircraft Co. Dept. S/A, 5827 W. Century Blvd. Los Angeles 45, Calif.** The valve design includes remote control of flow passage opening and closing, and remote disconnect.

Fail-safe over-ride controls are incorporated to prevent the nozzle from being opened when not connected and from being disconnected with valve or nozzle open. Leakage in the working pressure range is zero, and the valve features minimum spillage at disconnect. Changes in seal materials permit accommodation of a wide range of fluids. Size ranges are from two to eight-in. capacity. The assembly consists of nozzle and airborne poppet valve.

Write in No. 263 on Reader Service Card

TEMPERATURE CONTROL
for remote operation

A sensitive, remote bulb temperature control designed to control and indicate temperatures of gases, liquids and hotplates over a variety of ranges between—100 deg F to +600 deg F, is said to be suited for incubators, centrifuges, oxygen tents, sterilizers, ovens and similar applications, according to **United Electric Controls Co., Dept. S/A, 79 School St., Watertown 72, Mass.** It may be readily set to control and indicate anywhere within scale limits and calibration is easily checked.

The E36N has die cast aluminum black wrinkle finish enclosure, with black bakelite cover. The dial is aluminum with black figures on a white background. The bellows housing is nickel plated brass with copper capillary and bulb. Approximate weight is 2 lb 8 oz.

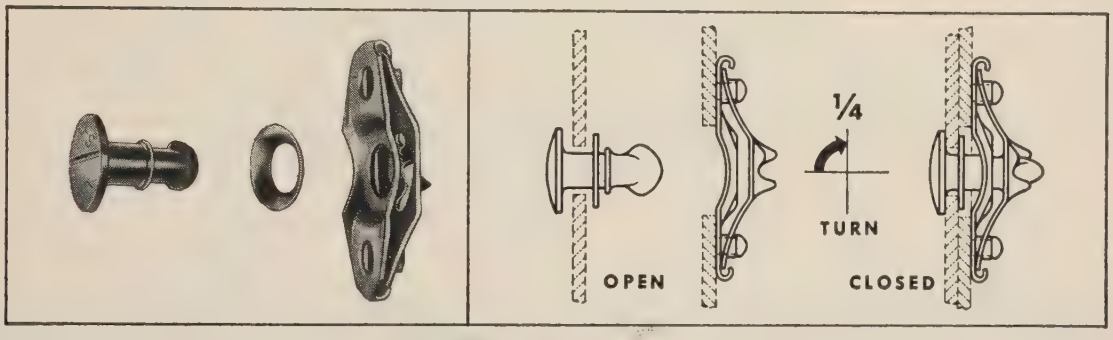
Write in No. 264 on Reader Service Card

more on page 2

THIS PANEL CAN BE
OPENED OR CLOSED
IN LESS THAN 2 SECONDS

LION ¼ TURN OPEN ¼ TURN CLOSED FASTENERS

ARE FAST, POSITIVE, RELIABLE



Installation of the three parts of the Lion Fastener, shown above, is quick but not critical. Unique in design and performance, these mil spec (MIL-F 5591A-ASG) fasteners make possible quick access and smooth positive locking by only a ¼ turn.

ALIGNMENT NOT CRITICAL

Both stud and receptacle "float" to accommodate misalignment. The hole, which retains the stud, is twice as large as the stud cross-section. This permits a float of .070 in all directions. The leaf spring receptacle also floats to accommodate stud position.

WIDE VARIATIONS IN STACK HEIGHT

Total sheet thickness may vary as much as +.035 and −.015 without affecting operation. A Lion stud, specified for .160 total thickness, for example, will accommodate any stack height between .195 and .145.

SWAGED-NOSE STUD

Extra strength and smooth operation are made possible by the swaged-nose design. All the metal in the stud goes to work. There are no thin cross pins, holes or milled slots to weaken the cross-section. Case hardening is further assurance of long, trouble-free service.

WIDE VARIETY

Lion Fasteners are available in 3 sizes—No. 5, No. 2, and Miniature. An assortment of head styles are supplied—oval, flush, wing, ring, notched or knurled—according to individual requirements.

FREE!

FASTENER HANDBOOK

Send for your free copy of Southco Fastener Handbook No. 9. Gives complete engineering data on Lion Fasteners and other special fasteners. Write to Southco Division, South Chester Corporation, 253 Industrial Highway, Lester, Pennsylvania.

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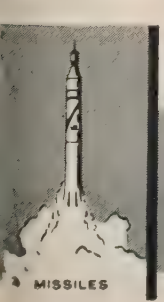
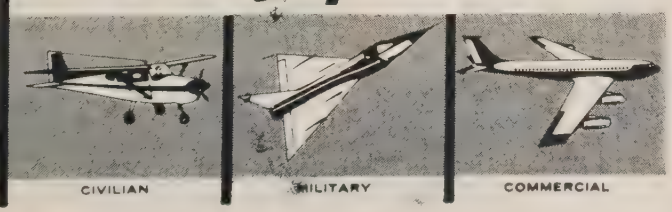
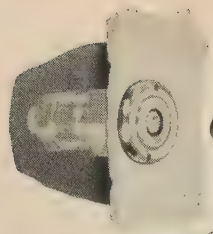




LION *Aviation* FASTENERS

one of the SOUTHCO LION FASTENERS

Write in No. 186 on Reader Service Card at start of Product Preview Section



new from OHIO

PUSH IN

EASY-ACTION, QUICK-CONNECT

TWIST OUT

AIRCRAFT OXYGEN OUTLET

This unique, flush-mounted oxygen outlet features a retractable, self-purging dust cap that never needs to be removed or pushed aside. It's easy to operate, too — just a soft push to insert and a quick twist to remove. Lightweight — (under 1 oz.) — this outlet is functionally designed — only one moving part. Here is the same principle that has been proved in thousands of hospital pipeline installations — now adapted for aircraft use!

For complete data and free engineering aid from specialists in oxygen piping systems, please write to Aviation Dept.

OHIO Ohio Chemical

OHIO CHEMICAL & SURGICAL EQUIPMENT CO.
Madison 10, Wisconsin
AIRCO (A Division of Air Reduction Company, Inc.)

Write in No. 187 on Reader Service Card

DC TO DC CONVERTER for missile flight

This Model M116 dc to dc is rugged and hermetically sealed to meet rigorous missile flight environments. Input voltage is 28v (—10 per cent) and output 350v at 110 ma. Includes regulation of ±5 per cent from 75 to 100 per cent of full load, a base plate temperature range of 30 deg F to 135 deg F, and a storage temperature from —65 deg F to +160 deg F, says **Alto Scientific Co., Dept. S/A, Palo Alto, Calif.** Output ripple is less than 1.2 V rms, and efficiency above 60 per cent. The instrument is protected against output short circuits and input spike voltages.

Write in No. 265 on Reader Service Card

HAND-CRANK MEGOHMMETER is redesigned

Series B Megohmmeter is a completely modernized version of a well known hand-crank, ratio-coil style of ohmmeter. The unit features several design improvements. Use of a generator with a 39-bar armature in place of the conventional 2-bar or 4-bar unit assures that resistance measurements are made at a reliable constant value of voltage, says **The Winslow Co., Dept. S/A, 701 Lehigh Rue, Union, N.J.**

The generator armature windings are skewed to prevent "slot lock" and the gear train driving the generator is mounted on needle bearings, effecting a large reduction in the cranking torque required. Leading instrument of the group is the Model 5G1000 Series B. It has a range of 0 to 1000 megohms, with full accuracy maintained over the entire range and meeting AST and military specifications.

Write in No. 266 on Reader Service Card

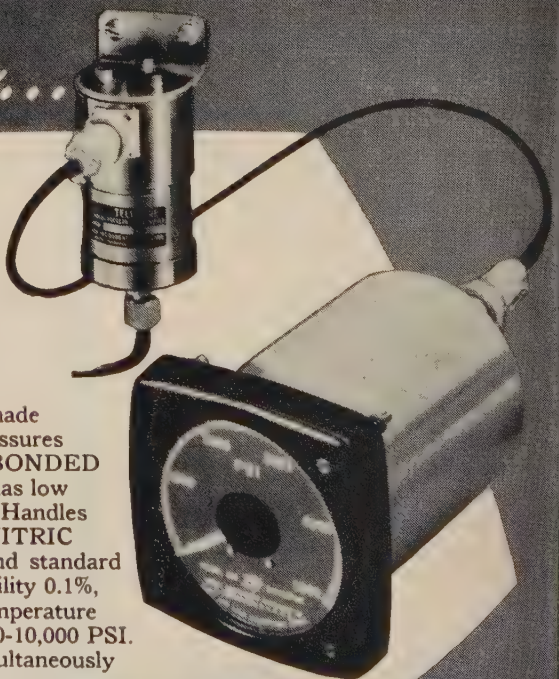
more on page 294

The standard of performance...

Taber®

TELEDYNE®

PRESSURE TRANSDUCER

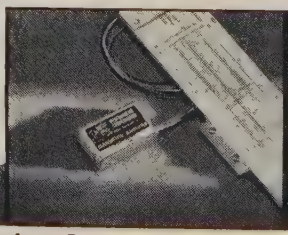


Compliance to specifications so rigid as to be impossible in many pressure transducers has made TELEDYNE the "standard" for measuring pressures in rocket, missile and jet systems. Because of BONDED STRAIN GAGE construction, TELEDYNE has low sensitivity to vibration or shock in any axis. Handles extremely corrosive media, including fuming NITRIC ACID. Features Pressure Cavity clean out and standard built-in pressure overload protection. Repeatability 0.1%, Linearity 0.3%, Hysteresis 0.25%, Ambient Temperature —150° to +275° F., Pressure Ranges: 0-50 to 0-10,000 PSI. With simple cable connection, can be used simultaneously with both Taber Indicator, as shown, and standard make Recorders and Controllers.

Write or telephone for literature and prices

TABER INSTRUMENT CORPORATION

Section 36 107 Goundry St.
North Tonawanda, N. Y.
Phone: LUdlow 8900 TWX - TON 277



Write for literature on our complete line of Miniature Transistor Amplifiers.

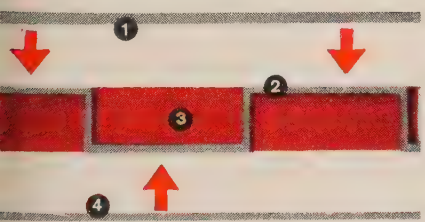
Write in No. 188 on Reader Service Card at start of Product Preview Section

Johns-Manville Announces... MIN-KLAD INTERLOK

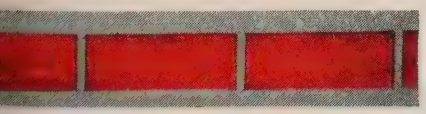
. . . a new structural system interlocking Min-K insulation and high-temperature reinforced plastic

Missile experience shows that in certain heat control situations no one material will perform as well as two (or more)—*an insulation with protective high-temperature facings.*

Problem is how to effectively combine these materials into a structurally strong unit? The answer is Min-Klad Interlok



1) Outer facing, 2) Interlocking web, 3) Core, any one of several Min-K formulations, and 4) Inner facing.



All the above components combine to provide a custom-made structural strong insulating system.

—a new structural system that interlocks Min-K insulation and reinforced plastic, metal or other high-temperature facings.

The result: one product that gives the missile designer every advantage of high-temperature plastic or metal foil—strength, toughness, rigidity! Erosion resistance! High heat capacity!

. . . plus the outstanding advantages of Min-K insulation—an insulating core that has the lowest thermal conductivity available for service temperatures up to 2000°F steady-state, and higher for transients. Min-K's thermal conductivity is actually lower than the molecular conductivity of still air.

Wide range of facings

For the hot face, the missile designer can specify Min-Klad Interlok in a wide variety of heat-resistant and/or ablating materials—asbestos-phenolic (ARP-40), and similar reinforced plastics, as well as stainless steel and other heat-resistant metal foils and meshes. For some requirements, the cool face can be made of a different material—for example, one that offers characteristics required for bonding or fastening to other surfaces and parts.

Like all J-M Aviation insulations, Min-Klad Interlok is factory-fabricated to your specifications into external skin panels, heat shields, cylindrical liners or component housings of any shape or size. Write today for technical specifications. Address Johns-Manville, Box 14, New York 16, New York. In Canada, Port Credit, Ontario.

JOHNS-MANVILLE JOHNS MANVILLE JM PRODUCTS

Write in No. 189 on Reader Service Card at start of Product Preview Section

NASA announces . . .

THE TRANSFER OF THE DEVELOPMENT OPERATIONS DIVISION OF THE ARMY BALLISTIC MISSILE AGENCY TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. Wernher von Braun, director of the new NASA Marshall Space Flight Center in Huntsville, Ala., pictured with NASA's Mercury Astronauts

Dr. Wernher von Braun and his space team join NASA

The National Aeronautics and Space Administration leads the nation's efforts to find, interpret and understand the secrets of nature as they are revealed in the laboratory of space.

This vigorous effort requires boosters for space vehicles which greatly exceed the thrust of any boosters currently available. For this reason, the $100 million Huntsville plant, together with its famous space team, are being transferred to NASA. The new NASA facility in Huntsville will be known as the George C. Marshall Space Flight Center.

NASA is now the largest civilian research organization in the United States. For details about outstanding professional opportunities, address your inquiry to the Personnel Director of any of these NASA centers:

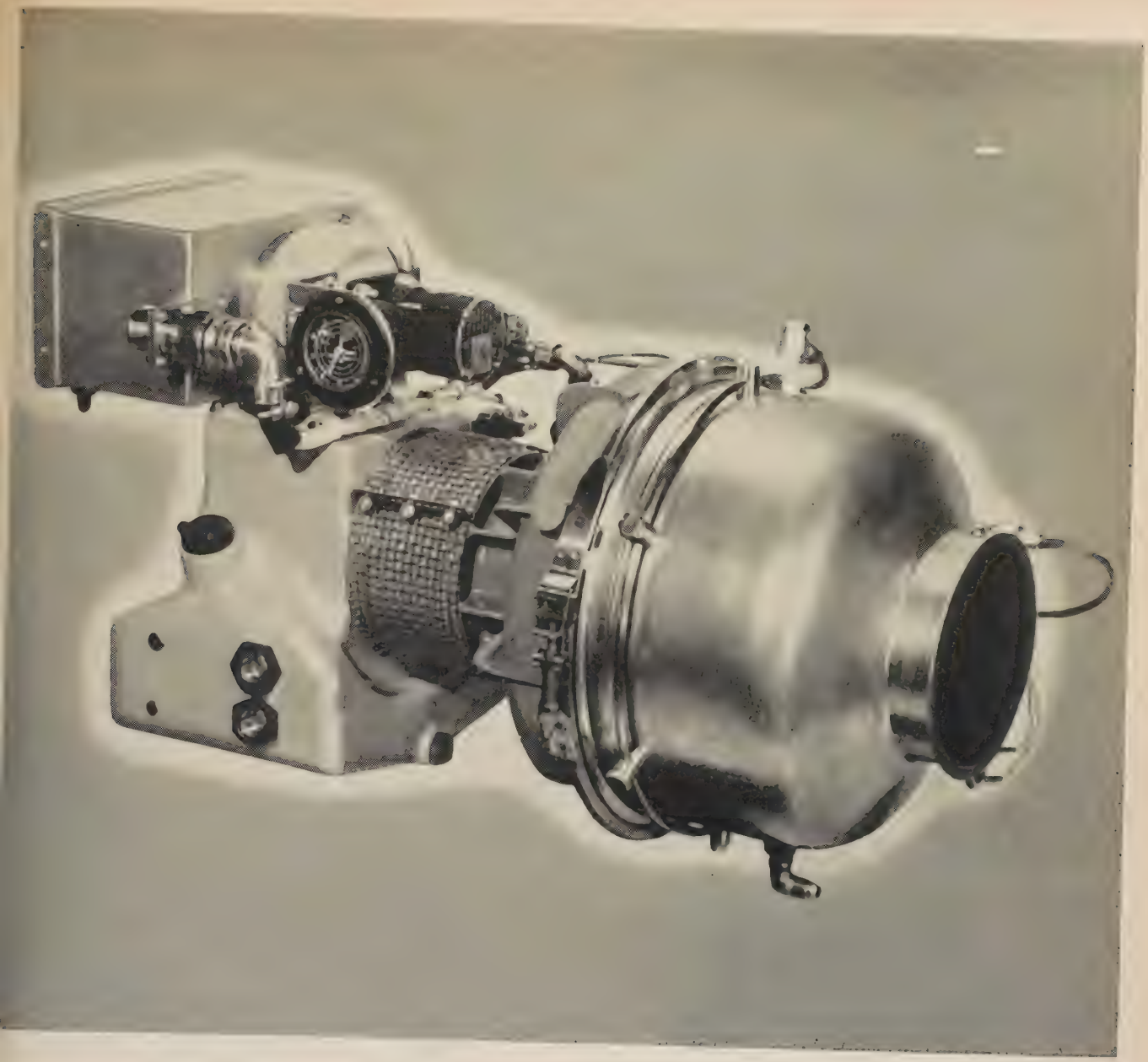
NASA Goddard Space Flight Center
Washington 25, D. C.

NASA Flight Research Center
Edwards, California

NASA George C. Marshall Space Flight Center
Huntsville, Alabama

NASA National Aeronautics and Space Administration

Check Employment Inquiry Form on Page 211



HELICOPTER APU

New Solar gas turbine 80 hp APU is only 12½ in. in diameter x 25 in.—weighs 59 lb

OLAR'S NEW gas turbine-powered licopter APU occupies only 2 cubic t—yet provides hydraulic or electri- power for complete checkout, for ound power and to start main pro- sion engines. It makes helicopters mpletely self-sufficient, able to erate from remote locations with no und support.

Powered by Solar's 80 hp *Titan* gas turbine, the lightweight unit is simple in design, easy to maintain, can be started instantly—without warmup—in temperatures from —65F to 130F and under wide atmospheric extremes. It operates efficiently on a variety of fuels.

Titan gas turbines are setting new standards of performance and reliability as propulsion units for one-man helicopters, in portable electric generators and in other applications. For details, write to Dept. H-110, Solar Aircraft Company, San Diego 12, Calif.

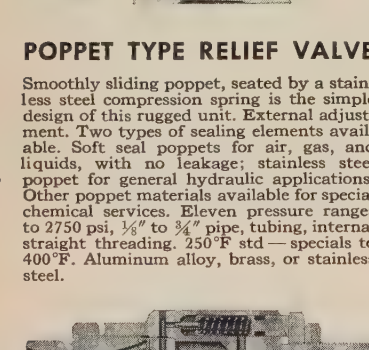
SOLAR
AIRCRAFT COMPANY

Write in No. 190 on Reader Service Card at start of Product Preview Section

REPUBLIC VALVES
FOR EVERY INDUSTRY

RELIEF VALVES
WITH
• EXCLUSIVE FEATURES
• SMOOTH OPERATION
• LONG LIFE

PILOT-OPERATED RELIEF VALVE

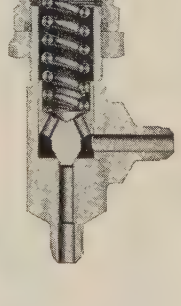


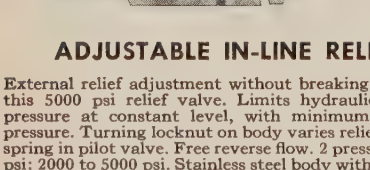
Hydraulic relief valve limits system's maximum operating pressure at constant level, though flow rate varies. No leakage loss below cracking pressure. Pilot valve controls pressure setting — main valve instantly conforms. Remote pilot available to lower setting of integral pilot control. 3 pressure ranges: 50 to 1200 psi; 1000 to 3000 psi; 2500 to 5000 psi. 50,000 tensile semi-steel body standard aluminum alloy to order. FMP or str. thread gasket seal bosses, ¼" to 1¼". Panel mounting bosses.

Modified units available as Sequence Operating Valves; and as Unloading Valves for clamping or other two-pressure applications.

POPPET TYPE RELIEF VALVE

Smoothly sliding poppet, seated by a stainless steel compression spring is the simple design of this rugged unit. External adjustment. Two types of sealing elements available. Soft seal poppets for air, gas, and liquids, with no leakage; stainless steel poppet for general hydraulic applications. Other poppet materials available for special chemical services. Eleven pressure ranges to 2750 psi, ⅛" to ¾" pipe, tubing, internal straight threading. 250°F std — specials to 400°F. Aluminum alloy, brass, or stainless steel.





ADJUSTABLE IN-LINE RELIEF VALVE

External relief adjustment without breaking line is the feature of this 5000 psi relief valve. Limits hydraulic system's maximum pressure at constant level, with minimum rise above cracking pressure. Turning locknut on body varies relief pressure adjustment spring in pilot valve. Free reverse flow. 2 pressure ranges: 50 to 2500 psi; 2000 to 5000 psi. Stainless steel body with hydraulic o-ring, –65° to 160°F standard. Packings for other fluids, and higher temperatures available. Flare or flareless tube connections ½" and ¾".

Distributors in principal cities coast to coast

CHECK RELIEF SELECTOR GLOBE NEEDLE PLUG

283

RM REPUBLIC MANUFACTURING CO.
15655 BROOKPARK ROAD • CLEVELAND 35, OHIO

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PHASE SHIFTER spans 360 degrees

Employing a sychro resolver, resistors and capacitors the Phase Generator provides continuous phase shift of carrier without amplitude change. The device is panel-mounted with all connections accessible from rear terminals, says **Theta Instrument Corp., Dept. S/A, 520 Victor St., Saddle Brook, N.J.**

Offering unusual life characteristics, the Phase Generator meets MIL-D-8512 and MIL-T-945A. Specifications include a phase accuracy of 30 minutes, a range of 360 deg and input voltage of 115, and an output voltage of 32V.

Write in No. 267 on Reader Service Card

TIME PROGRAMER for satellite use

Model 301 time programer is designed for missile and satellite applications. A simple analog-to-digital converter overcomes the usual resolution problem associated with electro-mechanical timers and insures high accuracy, says **Aztec Research Labs., Inc., Dept. S/A, 2324 Lafayette St., Santa Clara, Calif.**

Timing accuracy is essentially equal to the frequency regulation of the 400 cycle power supply used to drive the synchronous motor. Detailed specifications, drawings, and other information available on request.

Write in No. 268 on Reader Service Card

FREQUENCY GENERATOR is transistorized

Model 6261 incorporates a bimetallic tuning fork to provide a precision frequency. The unit has a 2.5 v output with frequencies from 300 to 4000 cps at accuracies of 0.1 to 0.01 per cent, says **Varo Mfg. Co., Inc., Dept. S/A, 2201 Walnut St., Garland, Texas.**

The oscillator circuit uses 2N334 and 2N235 silicon transistors, precision wire wound resistors and metallized mylar capacitors to achieve reliable operation to 125 deg C. The tuning fork and oscillator circuit are in a hermetically sealed can 1½ in square by 3¼ in high.

Write in No. 269 on Reader Service Card

FM TELEMETERING TRANSMITTER is completely modularized

Model 1483-A1 FM Telemetering Transmitter has an output of 2 to 6 W at 215 to 260 Mc. The unit features an AFC loop crystal controlled for ±0.005 per cent carrier stability, says **Telechrome Mfg. Co., Dept. S/A, 28 Ranick, Dr., Amityville, L.I., N.Y.**

Silicon transistors are used for low noise and high efficiency. The unit is lightweight and measures only 1.64 x 2.75 x 4 in.

Write in No. 270 on Reader Service Card

SPECTRUM ANALYZERS have detachable mixers

The use of external detachable coaxial and waveguide mixers in two spectrum Analyzers, Models LA-18 M and LA-20 M, provides greater sensitivity and more extensive range calibrated to 44 kmcps, says **Lavoie Labs., Inc., Dept. S/A, Morganville, N. J.**

Frequency calibration is accurate to ±0.1 per cent at operating frequency of local oscillator, and the units have a sweep repetition rate of from 0.5 to 30 cps, free-running or synchronized. Model LA-18 M features a 10 mcps to 44 kmcps range while Model LA20 M of similar design but smaller, lighter, and lower in cost, has a frequency range of 1 kmcps to 44 kmcps.

Write in No. 271 on Reader Service Card

more on page 296

OU GET COMPLETE INSPECTION WHEN YOUR "SPECS" READ HYATT

Hyatt Hy-Roll bearings are constantly checked through every stage of production. But performance is the payoff. And, that's why Hyatt insists . . . without exception . . . that every metric series Hy-Roll bearing be run on a special fixture to check noise level as a final test for quality. It's another of the many secrets of Hyatt reliability. Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey.

HYATT HY-ROLL BEARINGS

ROLLER BEARINGS HYATT IS THE WORD FOR GM RELIABILITY

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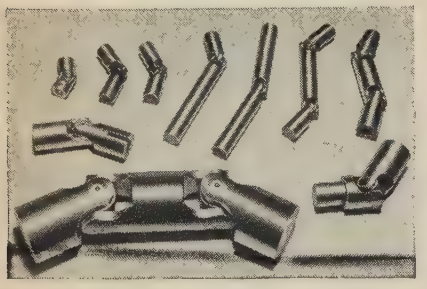
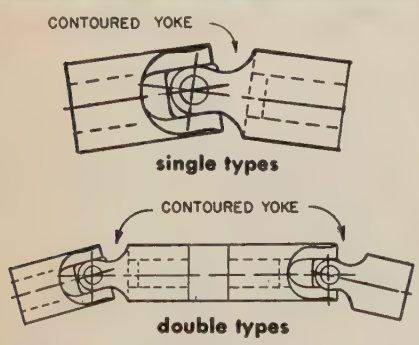
Lovejoy

UNIVERSAL JOINTS

INDUSTRY'S MOST COMPLETE LINE FOR EVERY SLOW SPEED APPLICATION





Check these features against your requirements:

Special Contoured Yoke—capable of operating at a maximum angular misalignment of 45° on hand-operated applications.

Static Torque—from 306 to 129,693 in.-lbs. at 12°, depending on size of joint.

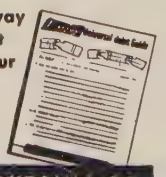
Horsepower Ratings—.54 to 207 at 100 rpm.

Tolerances—pins ground to .0005" ...forks concentric to within .001" ...precision accurate center blocks.

Standard Specifications—hub diameters ½ to 4"...bores ¼ to 2" ...lengths (single) 2 to 10⅝"; (double) 4 to 21¼". All specifications can be altered or special joints designed to individual requirements.

Get this handy guide

It's the quick and easy way to get the Universal Joint that is just right for your application. Request Bulletin 820.



LOVEJOY FLEXIBLE COUPLING CO.

4842 W. Lake St. Chicago 44, Ill.

Write in No. 193 on Reader Service Card

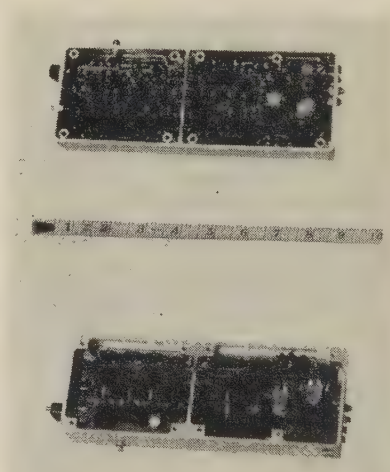
TIME DELAY SWITCH handles up to 50 amp

This switching device can handle 50 amp. without arcing, contact damage, radio interference, audible noise, or vibration. The switch is completely solid state, has no moving parts, and weighs only 3 oz., says George Harmon Co. Dept. S/A, 18232 Parthenia, Northridge, Calif.

Available up to 10, 16, 32 and 50 amp, the switches meet MIL-4-5757C, MIL-R-6106A, MIL-4-25018, and MIL-E-52782B. All components are hermetically sealed in a black anodized aluminum case 1¼x2 in.

Write in No. 272 on Reader Service Card

IF AMPLIFIERS are transistorized



A line of transistorized IF Amplifiers are available for the commonly used 30 and 60 Mc frequencies. Using silicon tetrode transistors the units have exceptionally fast recovery time wide dynamic range, says Remanco Inc., Dept., S/A 1630 Euclid, Santa Monica, Calif.

The units withstand temperatures up to 85 deg C and measure 7⅛x2¾x1⅛ in.

Write in No. 273 on Reader Service Card

PHOTOCELL has high sensitivity

Mullard ORP 10 photoconductive cell, made from indium antimonide, has a sensitivity in the infra-red radiation range up to 7.5 microns at room temperature. The actual spectral response range is from the visible to 8.0 microns, the peak response being 6.0 to 6.5 microns, says International Electronics Corp. Dept. S/A, 81 Spring St., New York 12, N.Y.

The cell has an impedance of about 75 ohms. The maximum dc value is 100 ma and the maximum case temperature is 70 deg C.

Write in No. 274 on Reader Service Card

more on page 298

IF IT'S QUALITY YOUR NEXT MOVE IS TO PRECISION TUBING

UNSURPASSED QUALITY AT REGULAR MILL PRICES

.010" O.D. to 1.125" O.D.

Copper, Brass, Bronze

• Why play checkers jumping from one supplier to another for better "buys" and better quality? You'll find your ultimate answer in the temper, straightness, roundness and size tolerances of Precision Tubing.

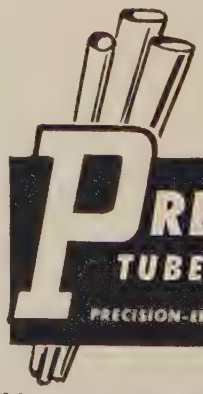
Precision Tubing is carefully tested and pre-tested in every step of production. Skilled craftsmen using modern drawing equipment and dies which are "quality-controlled" in our own shop assure Nth degree accuracy in every foot of tubing drawn. Electronically controlled annealing produces tubing to meet your most exacting specifications.

Precision also makes round, rectangular, Bourdon, oval or square, preformed to special shapes . . . in copper brass, aluminum, nickel and nickel-alloys, Ni-Span "C", phosphor-bronze and nickel silver.

Let our engineers help you improve quality and save money.

Write for full details to

PRECISION TUBE CO., INC.
North Wales, Pa.



GET YOUR COPY OF TUBING CATALOG

PRECISION TUBE COMPANY

PRECISION-EERS OF SMALL TUBING

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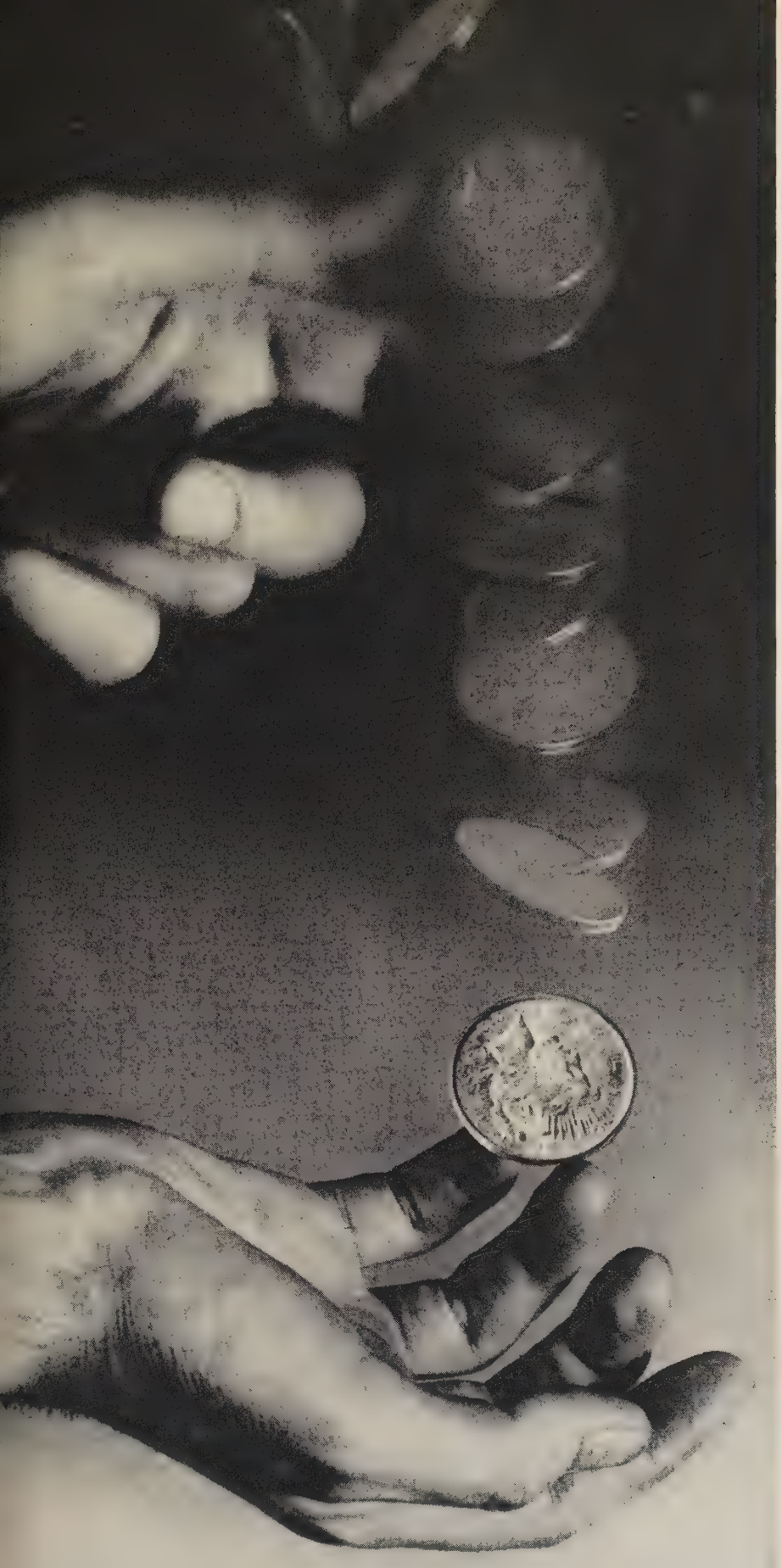

He took the luck out of heads or tails

This AMF engineer had a delicate problem: to accomplish the separation of the expended stages of a multi-stage rocket. If separation occurs too soon, thrust in the nearly burned out stage may exceed the aerodynamic drag, the tail overtakes the head, and...boom. A million dollar collision and no insurance.

His solution: An acceleration switch that turns the burned out stage loose at the right split second ...a switch that makes rockets think for themselves.

His switch is compact. It is designed to work in any missile at any range with any payload. It is ingeniously simple in conception, design, and operation. A spring is attached to a free swinging hammer, the spring force acting to pull the hammer against the contact plate. At calibration the spring can be set to oppose any G from 1 to 100. When the missile is launched, the hammer is held back by the acceleration forces until the stage decays to the desired separation G. When the spring force overcomes the forces of acceleration, the hammer comes forward, strikes the contact plate, and the circuit required to make separation is closed automatically. No guesswork, no luck, no *collision.*

Single Command Concept

This simple solution to a tricky problem reflects the resourcefulness of AMF people.

AMF people are organized in a *single operational unit* offering a wide range of engineering and production capabilities. Its purpose: To accept assignments at any stage from concept through development, production, and service training... and to complete them faster...in

- *Ground Support Equipment*
- *Weapon Systems*
- *Undersea Warfare*
- *Radar*
- *Automatic Handling & Processing*
- *Range Instrumentation*
- *Space Environment Equipment*
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GOVERNMENT PRODUCTS GROUP, AMF Building, 261 Madison Avenue, New York 16, N. Y.

AMF

gineering and manufacturing AMF has ingenuity you can use... **AMERICAN MACHINE & FOUNDRY COMPANY**

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TK test kits

Designed for the flight line testing of jet engine exhaust temperatures, engine temperature spreads, and a variety of gas temperature analysis applications in industry, Harco Test Kit Potentiometers are lightweight, portable, and compact. Shock-mounted, Harco Test Kits offer the built-in accuracy of fully self-contained instruments.

Harco Test Kits incorporate standard cells, galvonometers, and optical amplifiers . . . harnessing to read any number of thermocouples . . . packaged in polished, hardwood cases or military-type trunks.

Four different standard models . . . "specials" to meet individual requirements.

Write today for free technical literature and the name of your local Harco factory representative.

HARCO LABORATORIES, INC.,
Olive Street, New Haven, Conn.
Write in No. 195 on Reader Service Card

FM DISCRIMINATOR requires little space

Phase-lock detection techniques have been used in this transistorized FM subcarrier discriminator to provide maximum quality of information signals with high noise content and appreciably improved threshold characteristics, says **Vector Mfg. Co., Inc., Dept. S/A, 3040 Overland Ave., Los Angeles 34, Calif.** Discriminators are available for all IRIG (RDB) channels to 300 kc.

The unit's 2½ in width allows six channels to be mounted in the rack space of a conventional vacuum tube FM telemeter discriminator. Under two W of unregulated dc power are required. Filters and frequency-determined components are packaged as plug-in units.

Write in No. 275 on Reader Service Card

PRESSURE REGULATOR has integral relief valve

A pressure regulator for airborne or ground electronic system pressurization and other uses has been designed with an integral relief valve by **Applied Dynamics Corp., Dept. S/A, 32 N. Main St., Natick, Mass.** The valve in the Model 30-301 prevents pressure buildup due to thermal expansion of air or line surges.

Ratings of the unit include: inlet pressure of 40 to 60 psig and outlet pressure of 15 to 30 psig; a burst pressure of 500 psig at inlet and 80 psig at outlet; and a pressure variation at set point of plus or minus one psig. The 0.75-lb unit will operate in any position and over a temperature range of —70 to +175 deg F.

Write in No. 276 on Reader Service Card

more on page 300

871A

Improved **FEL-PRO C5-A** "HI-TEMP" ANTI-SEIZE THREAD COMPOUND

delivers *MORE* dollar value at same LOW COST!

All These New Improvements—

NEW • Lower breaking and running torque
NEW • Non-settling, non-hardening, homogenized composition
NEW • Can be used in below freezing weather
NEW • Increased lubricating and sealing qualities
NEW • Prevents rust and corrosion

Now in tubes and cans

FREE TEST SAMPLE PROVES HOW!

You'll save countless man hours and avoid costly replacement of broken studs, bolts, etc., with the protective cushioning action provided by the colloidal copper composition of C5-A. Improved C5-A Lubricates and Seals for fast, easy application and removal. Gives same protective performance even after high-pressure, high-temperature use, up to 1800° F. Can be used on all metals and plastics.

FELT PRODUCTS MFG. CO.
Dept. 52, 7450 N. McCormick Blvd., Skokie, Illinois

- ✓ Ends seizing and galling even up to 1800° F.
- ✓ Reduces wrench torque
- ✓ Stops needless stud breakage
- ✓ Permits repeated re-use
- ✓ Speeds assembly and disassembly
- ✓ Prevents galling of stainless steel

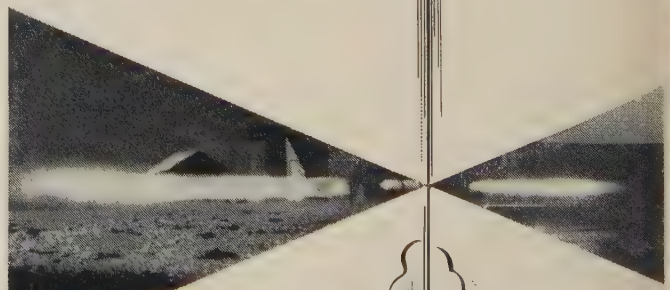
TRY C5-A NOW . . .
You'll find it ideal for aircraft uses such as slip joints, manifold studs, turbo blowers, etc. *Write for your free test sample today!*

Write in No. 196 on Reader Service Card

35 different types of liquid propellant engines including

- Gas-pressure engines
- Turbo-pump engines
- Turbojet-driven engines

- 53,000 ground-tests performed to-date
- More than 4,000 firings in flight on 8 different types of aircraft.
- 35 different types of solid-propellant engines including boosters and sustainers up to 450,000 lb/sec total impulse.



Société d'Étude de la Propulsion par Réaction
1, VOIE DES SABLES
VILLEJUIF (SEINE) • TÉL. : ITA. 57-69

SEPR

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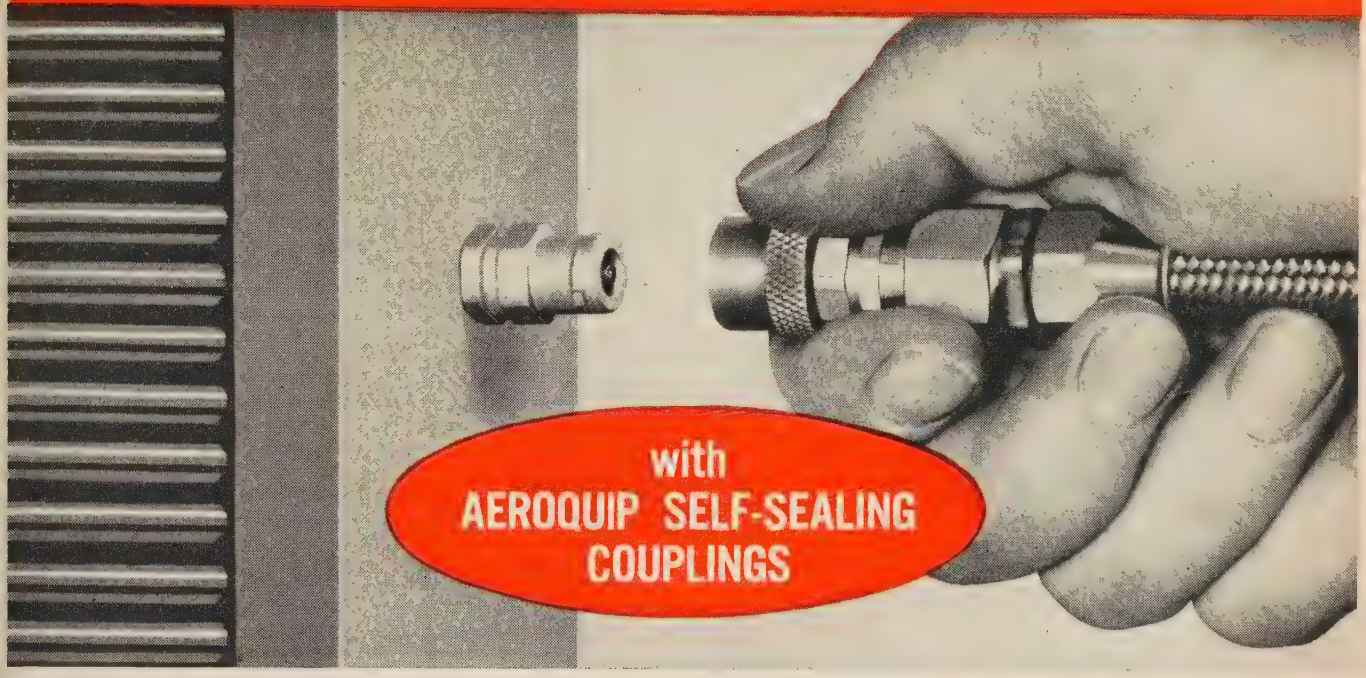
IGEP

CONNECT AND DISCONNECT ELECTRONIC COOLANT SYSTEM LINES

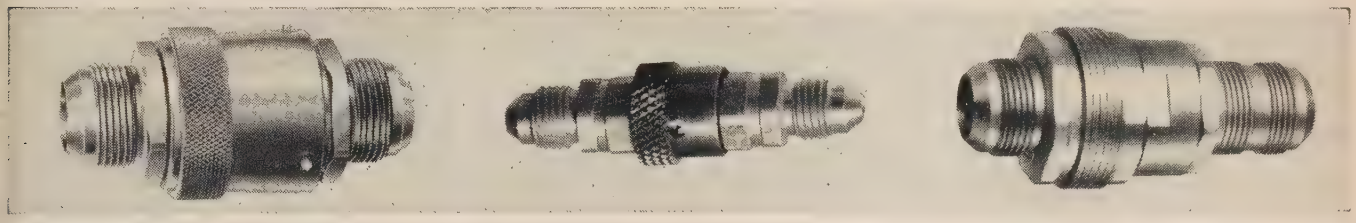


with AEROQUIP SELF-SEALING COUPLINGS

Now, you can connect and disconnect coolant lines on electronic equipment in seconds, using Aeroquip Self-Sealing Couplings. Aeroquip offers a range of quick-disconnect couplings to meet requirements of all airborne and ground support electronic systems. Types include miniaturized couplings for compact airborne systems (the miniaturized coupling pictured above weighs only .037 lbs.) as well as standard sizes through 1½". Operating features of Aeroquip Couplings include high flow rates and a variety of connection and disconnection methods, with little or no fluid loss.

Aeroquip's engineering staff, the largest and most complete in its field, has developed literally hundreds of specialized quick-disconnect couplings. If you have a fluid line connection or disconnection problem, Aeroquip's unmatched experience and resources are at your service.

Fill in and mail the coupon below for information and engineering assistance.



3750 Series Quick Disconnect Coupling for ¼" to 1½" lines features visual lock indicator pins for foolproof connection. Full flow design with low pressure drop.

1010 Series Miniaturized Coupling for airborne electronic systems. Lightweight (.037 lbs.) and compact envelope design permits use in confined space. For ¼" O.D. tube size lines.

3900 Series PUSH-PULL Couplings offer very low pressure drop, and ease of connection and disconnection with no fluid loss in a wide range of sizes. Designed for low lubricity fluids such as FC-75.

EXAMPLES OF UNLIMITED COUPLING DESIGNS BY

Aeroquip

AEROQUIP CORPORATION, JACKSON, MICHIGAN
AEROQUIP CORPORATION, WESTERN DIVISION, BURBANK, CALIFORNIA
AEROQUIP (CANADA) LTD., TORONTO 19, ONTARIO
AEROQUIP PRODUCTS ARE FULLY PROTECTED BY PATENTS IN CANADA, U.S.A. & ABROAD

Aeroquip Corporation, Jackson, Michigan SA-5

☐ Please send me your Coupling Bulletin No. 615.

☐ Please have an Aeroquip Sales Engineer contact me.

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TITLE_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE_____ STATE_____

Write in No. 197 on Reader Service Card at start of Product Preview Section

NEW SOLID STATE FREQUENCY STANDARDS OUT-PERFORM MECHANICAL TYPES — COST NO MORE!

- **New crystal controlled "L" models hold .025% to .005% tolerance at −55°C to +100°C, over 25 to 31 Vdc input, 5-2000 cps vibration at 15 g simultaneously.**
- **Qualified to MIL E-5272 C. Usable for airborne systems, facsimile, yet competitively priced with same-application mechanical types.**
- **Outputs up to 50 milliwatts, sine or square wave. Distortion, less than 10%. Weight, less than 4.5 ounces. Dimensions, 1½" x 1½" x 2¼".**

Want to escape the price-versus-performance squeeze? Take your pick from a whole series of Model "L" Secondary Frequency Standards. These units are the first of their kind that offer space-saving design, improved performance and reliability *without price penalty*.

Send for engineering data. Write or telephone for prompt application assistance to Time Control Systems Division.

DEI CLEVELAND

Designers for Industry Inc.

4241 Fulton Parkway • Cleveland 9, Ohio • SHadyside 9-0700

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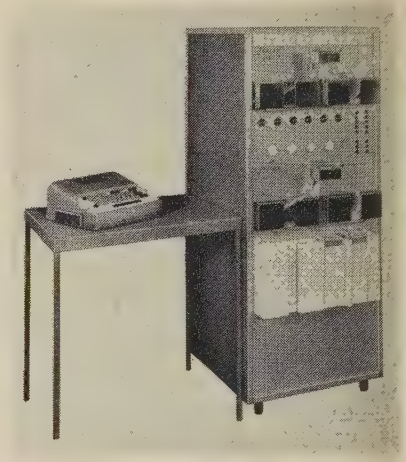
EDITING CONSOLE duplicates paper tapes



The console consists of a numerical keyboard, a control and comparison section with 6-digit decimal readout, two tape readers and one tape perforator. The unit duplicates and verifies at a rate of 60 characters per sec, says **Tally Register Corp., Dept. S/A, 5300 14th Ave N.W. Seattle 7, Wash.**

Tape may be produced in several modes from source data enteresat the keyboard. The unit has a keyboard visual display and shift register to eliminate copying errors and automatic error alarms and tape corrections without overpunching or splicing. Tape may also be produced directly from another tape placed in one of the readers. The unit accepts standard tape widths of 0.687, 0.875 and 1,000 in.

Write in No. 278 on Reader Service Card

ISOLATION SYSTEM for navigation gear

Elimination of environmental shock and vibration effects without compromising the precision of initial angular alignment in gyros and other navigation equipment is possible with this new vibration isolation system, says **Allied Research Associates, Inc., Dept. S/A, 43 Leon St., Boston 15, Mass.** The system permits omnidirectional rectilinear motion but maintains high-stiffness constraint against rotation.

Excellent shock attenuation, improved vibration isolation at high frequencies, and decoupled angular and translational modes are provided by the mount assembly, which uses C-shaped metal springs to obtain its stiffness characteristics. System damping is provided by elastically-supported unit dampers. One of the two available mount configurations features an angular returnability of 30 sec of arc, and the devices may be used over a wide temperature range.

Write in No. 279 on Reader Service Card

more on page 302

SIZE 8

SYNCHROS • SERVO MOTORS • MOTOR TACH GENERATORS

400 Cycle: Many for 125°C operation . . . Higher for special applications

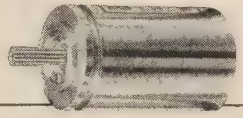
Many Immediately Available From Stock in Small Quantities

SIZE 8 SYNCHROS

Highly Stable. Minimum Error Variation from −55°C to +125°C

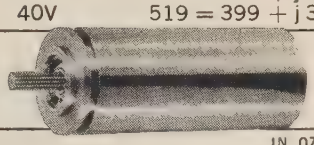
OSTER TYPE	CLASS	INPUT VOLTAGE	INPUT CURRENT AMPS	INPUT WATTS	OUTPUT VOLTAGE	PHASE SHIFT (° LEAD)	ROTOR RESISTANCE (OHM)	STATOR RESISTANCE OHMS	Z_{ro} OHMS	Z_{so} OHMS	Z_{rss} OHMS	NULL VOLTAGE (MV)	MAX. ERROR FROM E.Z. (MIN.)
4253-01*	LZ-CT	11.8	.087	.21	23.5	9.0	157.0	24.0	212+j722	28+j119	263+j69	30	±7
4269-01*	Diff	11.8	.087	.21	11.8	9.0	35.0	24.0	37+j139	28+j124	47+j13	30	±7
4273-01**	XMTR	26.0	.100	.54	11.8	8.5	34.0	12.0	48+j255	12+j45	82+j31	30	±7
4277-01*	HZ-CT	11.8	.030	.073	22.5	8.5	316.0	67.0	500+j1937	79+j350	594+j182	30	±7
4261-01**	Resolver	26.0	.043	.39	11.8	15.0	162.0	22.0	208+j612	34+j159	243+j77	30	±7

*Stator as Primary **Rotor as Primary



SIZE 8 SERVO MOTORS

OSTER TYPE	RATED VOLTAGES	Z = R + jX	IN. OZ. STALL TORQUE	RPM NO LOAD SPEED	WATTS PER PHASE	GM. CM. ROTOR INERTIA	LENGTH IN. MAX.	WEIGHT OZ.	T/I RATIO RAD/SEC²
5004-01	26V 26V	288 = 226 + j 176 294 = 238 + j 174	.15	6200	2.0	.47	0.863	1.2	22,500
5004-02	26V 36V	288 = 226 + j 176 526 = 409 + j 332	.15	6200	2.0	.47	0.863	1.2	22,500
5004-03	26V 40V	288 = 226 + j 176 715 = 582 + j 415	.15	6200	2.0	.47	0.863	1.2	22,500
5004-09	26V 40V	230 = 190 + j 131 519 = 399 + j 332	.20	6200	2.5	.47	0.863	1.2	30,000



SIZE 8 MOTOR TACH-GENERATORS

OSTER TYPE	RATED VOLTAGES	Z = R + jX	IN. OZ. STALL TORQUE	RPM NO LOAD SPEED	WATTS PER PHASE	GM. CM. ROTOR INERTIA	LENGTH IN. MAX.	WEIGHT OZ.	T/I RATIO RAD/SEC²	GENERATOR VOLTAGE	INPUT WATTS	OUTPUT VOLTS PER 1000/RPM
6204-01	26V 40V	230 = 190 + j 131 519 = 399 + j 332	.20	6000	2.5	.65	1.728	2.5	21,800	26	2.5	.25
6204-03	26V 26V	230 = 190 + j 131 230 = 190 + j 131	.20	6000	2.5	.65	1.728	2.5	21,800	26	2.5	.25

Oster®

The Size 8 400 Cycle Servo Motor Tach Generators listed above have 150° max. cont. frame temperature, 110 MA input current, ±5° phase shift and Null Voltage (Total R. M. S.) of 15 millivolts.

OTHER PRODUCTS INCLUDE:

Resolvers
Computers
Indicators
Servo Mechanisms
Servo Torque Units
DC Motors

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Engineers For Advanced Projects:

Interesting, varied work on designing transistor circuits and servo mechanisms.
Contact Mr. Robert Burns, Personnel Manager, in confidence.

Write in No. 199 on Reader Service Card at start of Product Preview Section

DALIC SELECTIVE PLATING for ELECTRONIC COMPONENTS

Plating circuit contacts without dismantling electronic components.

Quick Accurate Way to Plate:

- Semi-Conductors.
- Flexible Circuits.
- On site field repair of Electronic Computer Contacts.

Speeds Production in:

- Automatic plating of Transistor Tabs.
- Gold-plating on Aluminum.
- No-flux soldering on Aluminum and Stainless Steel.

Plate selected areas rapidly without disassembling components. Dalic Process accurately controls thickness of deposits. Produces quality plating.

No Immersion Tanks. Mobile Equipment.

Plating equipment can be moved to the job. Quick, easy to use with Dalic hand-stylus, power pack, and the Dalic plating solutions. Mechanized production can be devised.

Write for Descriptive Brochure.

SIFCO METACHEMICAL, INC.

935 East 63rd Street • Cleveland 3, Ohio

A Subsidiary of
The Steel Improvement & Forge Co.

AGENTS

MARLANE DEVELOPMENT CO.
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PIDDINGTON & ASSOCIATES LTD.
3219 East Foothill Blvd.
Pasadena, California

D & S AVIATION CO., LTD.
671 Laurentides Blvd.
Pont Viau, Montreal, Quebec

Write in No. 200 on Reader Service Card

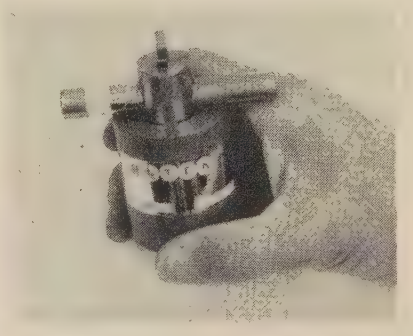
SHUT-OFF VALVE is inertia-operated

Valve 35-2064-000, a normally-open type closes only with g loading to prevent build up of fluid pressures in a liquid fuel system, says **Aero Supply Mfg. Co., Inc., Dept. S/A, Corry, Pa.** The valve opens again as acceleration diminishes.

Flow rate is nine gpm with a pressure drop of .5 psi maximum. The lightweight valve is available in any line size.

Write in No. 280 on Reader Service Card

HIGH-VACUUM PUMPS are lightweight



Series 110 UlteVac Electronic High-Vacuum Pumps are designed for use as permanent appendages on large electron tubes, and are also suitable for miscellaneous types of industrial and laboratory applications. Pumping 0.7 liter per sec the pump and accompanying magnet together weigh 1.6 lb and the magnet has a two in dia, says **Ultek Corp., Dept. S/A, 920 Commercial St., Palo Alto, Calif.**

Having a cold-cathode discharge and a body fabricated of stainless steel, the pumps are engineered for long life. In operation, the pumps draw a current in a linear relationship with pressure. This permits the pump to double as a vacuum gage.

Write in No. 281 on Reader Service Card

CERAMIC BUSHINGS for high temperatures

These high-temperature ceramic bushings are capable of withstanding 2000 deg F continuous operating temperatures. They are in diameters to 0.28 inches, according to **Duramic Products, Inc., Dept. S/A, 426 Commerical Ave., Palisades Park, N. J.** Standard tolerances are held to ±½ per cent and as close as ±.0002 inches both on diameter and wall thicknesses.

The bushings are used in electrical insulators, semiconductor tooling, spot welding locators, furnace brazing jigs, welding nozzles, glass working tools, and induction heating locators.

Write in No. 282 on Reader Service Card

more on page 304

Complete Facilities for all molded and machined parts and...

A Complete Stock of
SHEETS—RODS—TUBES

Expanded Facilities and Increased Engineering Personnel are all part of IPECO's New Look...designed to serve more industrial users, *better*

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INDUSTRIAL PLASTIC
AND EQUIPMENT COMPANY, INC.

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TEFLON: REGISTERED TRADE MARK - DUPONT
KEL-F: REGISTERED TRADE MARK - 3M

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"TORQUE WRENCH" MANUAL

SENT UPON REQUEST

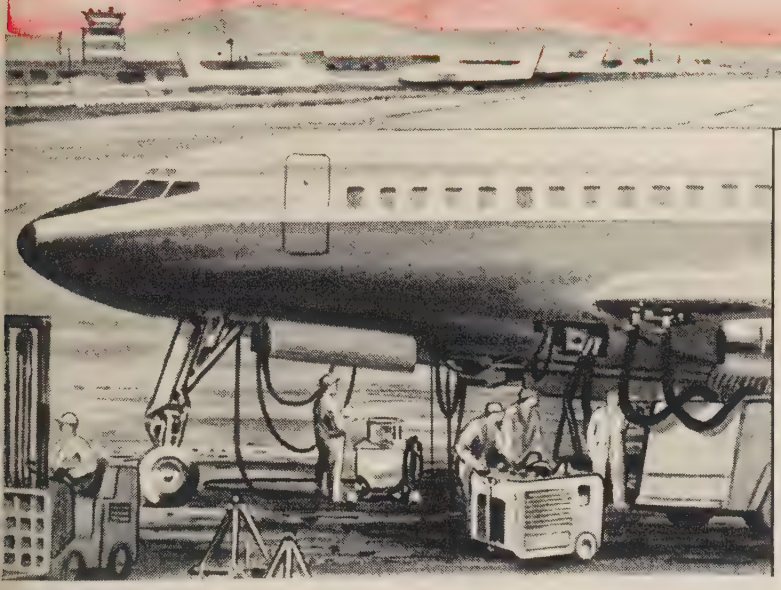
Formulas
Applications
Engineering Data
Screw Torque Data
Adapter Problems
General Principles

P.A. STURTEVANT CO.
ADDISON QUALITY ILLINOIS

Write in No. 202 on Reader Service Card

On the Ground as in the Air . . .

RELIABILITY rides on BEARINGS



Whatever the weapons system, the reliability of ground support equipment rides on bearings. Many such bearings have solid cylindrical rollers.

Reliability statistics prove that where load-ability or life expectancy are vital . . . and both space and weight are limiting factors . . . roller bearings do a better job over a longer period.

Rollway's long experience in roller bearings for military and commercial equipment is reflected in our new *Air-Rol* Data Book. It contains new and vital criteria for bearing selection. A letter on company stationery will bring it to any qualified person by return mail. Rollway Bearing Company, Syracuse, N. Y.

ROLLWAY®

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BEARINGS

COMPLETE LINE OF RADIAL AND THRUST CYLINDRICAL ROLLER BEARINGS

ENGINEERING OFFICES: Syracuse • Boston • Chicago • Detroit • Toronto • Pittsburgh • Cleveland • Seattle • Houston • Philadelphia • LosAngeles • SanFrancisco

Write in No. 203 on Reader Service Card at start of Product Preview Section

The quickest most practical way to put strong threads in soft materials the TAP-LOK® INSERT

SLOTTED

IN SOFTER METALS AND PLASTICS... Has full V-form external threads to provide maximum locking torque and permit wide choice of mating hole sizes. Recommended for soft aluminum, zinc die castings, sand castings and plastics. Meets requirements of MIL-MS-35914.

H-SERIES

FOR HIGHER STRENGTH MATERIALS... Has heavy wall and truncated root external thread and three-hole cutting edges for hard-to-tap higher-strength materials and to meet MIL and other specs calling for Class 3B thread fit for gaging after installation.

P-SERIES

FOR SPARK PLUG SOCKETS ... Designed to eliminate thread wear and renew damaged threads in spark plug sockets in aluminum cylinder heads. Available from stock for standard plug sizes to meet most common needs.

W-SERIES

FOR WOOD... Has coarse pitch external threads offering maximum strength in combination with ability to be driven into thin sections without splitting them. For furniture, cabinets and other wooden parts where strong, permanent threads are needed, or that are frequently assembled and disassembled.

Another fastener development from –

TAP-LOK / GROOV-PIN CORPORATION

1121 Hendricks Causeway, Ridgefield, N. J.

Write in No. 204 on Reader Service Card

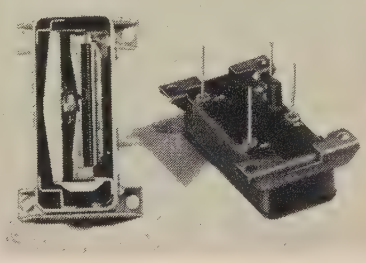
EPOXY LAMINATE has glass base

A glass-base, epoxy resin laminated plastic for use in both normal and elevated temperature applications has been announced by **Taylor Fibre Co., Dept. S/A, Norristown, Pa.** It meets the specifications for NEMA grade G-11 and military grade MIL-P-18177B-Type GEB.

A one-eighth inch thick sheet retains at least 68 per cent of its flexural strength after one hour exposure at 300 deg F.

Write in No. 283 on Reader Service Card

TIME-DELAY RELAY is rugged



Type PT thermal time-delay relay may be operated under vibration of 20 g's up to 2000 cps and a shock of 50 g's for 11 millisec. There is no resonance below 2000 cps, says **G-V Controls Inc., Dept. S/A, Okner Parkway, Livingston, N. J.**

Operating time delays of the SPST relay are 3 to 60 sec. Units are rated at 2 amp at 115 V ac or 28 V dc and are hermetically sealed in a 1 3/16 x 2 1/4 x 3/4 in rectangular case. Weight is about 2 oz.

Write in No. 284 on Reader Service Card

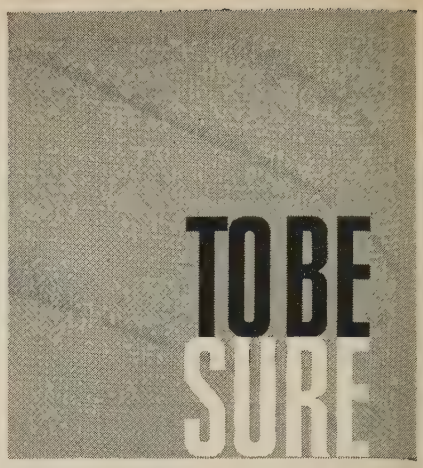
PRECISION GAGE for testing uses

This test gage is being used in laboratory and field and in the missile industry as a substitute for dead weight testers for rapid and economical calibration of less accurate gages, transducers and other pressure measuring devices. The design is said to permit a 360 deg linear dial, with the movement calibrated to the dial with an accuracy of 0.15 per cent or better. The 12-inch 360 deg dial gives the equivalent scale length of a 16 inch 270 deg dial but provides superior readability with high accuracy in a smaller gage, according to **Martin-Decker Corp., Dept. S/A, 3431 Cherry Ave., Long Beach 7, Calif.**

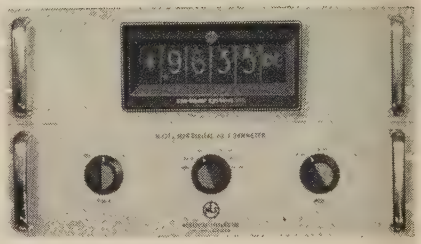
The precision test gages are manufactured with Bourdon tubes of Ni-Span C, a high nickel steel with small amounts of chromium, titanium and other elements.

Write in No. 285 on Reader Service Card

more on page 306



Specify the Finest Digital Voltmeter Made



NLS SERIES 20... When the combination of reliability, speed and accuracy is of uncompromising importance — you can't afford to gamble on "second best" digital measuring equipment! NLS Series 20 instruments are field-proven in the most critical applications — missile and electronic systems checkout, automatic process monitoring, sophisticated laboratory research. Be sure—specify NLS Series 20, the instruments selected by major missile manufacturers after thousands of hours of competitive life testing.

Features: M24 measures DC voltage, voltage ratio or resistance in a third of a second, V24 measures DC voltage and voltage ratio at same speed . . . both instruments feature advanced transistoried circuitry and mercury-wetted relays with life in excess of 3 billion readings . . . ±one digit accuracy on DC voltage and voltage ratio . . . completely automatic operation . . . plug-in modular construction . . . AC or low level measurements with plug-in accessories . . . output connectors for continuous data logging. Ranges: DC voltage ±.0001 to ±999.9; DC voltage ratio to ±.9999; resistance .1 ohm to 1 megohm. M24, complete: $5,650.00. V24, complete: $4,950.00. Write today for complete data.

NLS *Originator of the Digital Voltmeter*

non-linear systems inc.

DEL MAR (SAN DIEGO), CALIFORNIA

Write in No. 205 on Reader Service Card

How Superior Breaks the Spec Barrier in Stainless Hydraulic Tubing

Just meeting specifications isn't enough when you are producing stainless steel aircraft hydraulic tubing. More and more customers are asking for and getting "above normal specification" tubing from us, even though we now produce to 8 current MIL, AMS and AN Specifications.

Here are just a few of the *extras* requested by Superior customers in recent orders:

EXTRA LOW DEFECT LEVEL. We satisfied requirements by special production, verified by Eddy current inspection, the tubing being below .065 in. wall.

SPECIAL SPRING-BACK CHARACTERISTICS. Customer's requirements were met by producing the tubing to limited cold-worked temper range.

RESTRICTED MICROINCH FINISH LIMITS. Special drawing procedures and surface roughness inspection were used to achieve the finish required by the customer.

It is usual for Superior to do the unusual, since it is the world's most experienced producer of small-diameter tubing and has the widest range of analyses and sizes, plus the specialists to help solve puzzling tubing problems.

If you have a problem involving high-quality aircraft tubing and want the best combination of physical and mechanical properties, including high strength, ductility, fatigue and corrosion resistance, and good working qualities, consult us. We specialize in Seamless and Weldrawn® stainless steel aircraft hydraulic tubing in AISI Types 304, 321 and 347 in sizes ranging from .012 through 1.125 in. OD. Ask for Catalog 21, Superior Tube Company, 2038 Germantown Ave., Norristown, Pa.

Stainless Steel

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

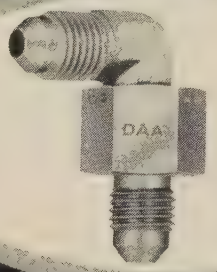
All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

Write in No. 206 on Reader Service Card at start of Product Preview Section

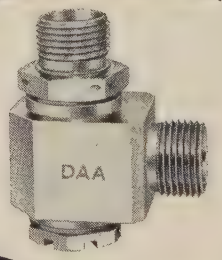
DUMONT self-aligning swivel fittings automatically compensate for any misalignment up to 14°.

Every DUMONT self-aligning swivel has a 360° rotation with a comparatively low torque rating.



DUMONT self-aligning units are available with several different configurations (any angle) and fitting ends to assure their flexibility and usefulness.

DUMONT'S pressure balanced plane swivel, with its 360° rotation, develops less resistance to rotation, than any other known rotary union.



ADAPTABILITY

IN FLUID ROTARY UNIONS*

Whether combined to form a complex or used individually, these rotary unions, produced by DUMONT ENGINEERING, offer the utmost in adaptability.

These units offer an excellent solution for many oscillating or rotating fluid line problems and have such a universal application that they are suitable for nearly all types of liquids and gases. They are also suitable for operation pressures up to 5,000 PSI. To insure its function and reliability, every unit undergoes rigid inspections for quality control. These units have also been fully tested and qualified per mil Specs MIL-J-5513A and MIL-E-005272-B.

Many special swivel designs, sizes and fitting ends are available. Our engineering consultants are well qualified to assist you in the selection, design and/or development of a unit to fit your specific needs.

* PATENTS APPLIED FOR

For complete information and specifications write or phone:

DUMONT ENGINEERING

DEPARTMENT S 1, 1401 FREEMAN, LONG BEACH, CALIFORNIA
PHONE: SPruce 5-1131 • GEneva 3-4931

Write in No. 207 on Reader Service Card

COUPLING *is self-sealing*

This quick-disconnect self-sealing coupling is for use with hydraulic fluids such as OS-45, Oronite 8515, and MIL-H-5606A oil. It is capable of operation in a temperature range of —65° F to 400° F, according to **Arkwin Industries, Inc., Dept. S/A, 648 Main St., Westbury, N.Y.** Two classes of Type III systems are available: Class 600, 600 psi rated pressure furnished in 1¼", 1½", and 2" tube sizes; Class 3000, 3000 psi rated pressure furnished in ¼", ⅜", ½", ¾", and 1" tube sizes.

The high temperature, high pressure units, when used with fluids such as OS-45 and designed for use in Type III systems are fabricated of corrosion resistant stainless steel.

Write in No. 286 on Reader Service Card

SOLAR CELLS *are ten per cent efficient*

These Silicon Solar Cells are capable of converting ten per cent and higher of the radiant energy falling on their surface. This makes these the most efficient solar converters currently available, claims **International Rectifier Corp., Dept. S/A, 1521 E. Grande Ave., El Segundo, Calif.**

These rectangular cells are now watts per sq ft of active cell area available for both commercial and military applications, and are capable of providing an output of about nine watts per sq ft of active cell area in bright sunlight. Individual cells are obtainable, with or without colorcoded pigtail leads, in sizes ½ x one cm., ½ x two cm., and one x two cm.

Write in No. 287 on Reader Service Card

FILL MONITOR *eliminates lox spillage*

A portable, battery-powered monitor has eliminated the need of overfilling aircraft Lox converters to assure full charging, says **Consolidated Airborne Systems, Inc., Dept. S/A, 900 Third Ave., New Hyde Park, N.Y.** The Model TLF-8 fill monitor makes use of the converter's probe for level sensing, and it is applicable to other cryogenic systems using capacitance-type level sensors.

No disassembly or removal of Lox system components is necessary to permit use of the monitor. It may be used for all standard aircraft liquid oxygen flasks and as a bench tester for checking converters in storage. The monitor obtains its power from an internal nine-V dry cell and a 14.8-V mercury cell, with an operating life of over 100 hrs. Weight of the unit is about ten lbs, and dimensions are 11½x9½x7¾ in.

Write in No. 288 on Reader Service Card

OVENS *feature control sensitivity*

A patented system in the Ultra-Temp ovens proportions external thermocouple resistance automatically to provide greater sensitivity and uniformity of control operation, according to **Blue M Electric Co., Dept. S/A, 138th & Chatham St., Blue Island, Ill.** Control point is plus or minus two deg F.

The ovens, which have a range of 66 to 649 deg C, also employ the Con-Wate mechanical air convection method to maintain constant weight of air and constant efficiency at all temperatures over the range. The result is achievement of greater specimen-test uniformity throughout a larger working volume. Stainless steel construction is used for the interior and heavy gauge oven steel for the exterior. Other features include expanded adjustable shelves, indirect V-belt drive, and built-in overload protection. The four standard sizes range from one to 11 cu ft capacity.

Write in No. 289 on Reader Service Card

more on page 308

ABLATION BY CTL

Heat dissipation by the gradual and controlled separation of matter—an area of intense research at CTL for several years. If heat flux on any surface in your design ranges from 50 btu/ft² sec to 50,000 btu/ft² sec, benefit from CTL's work with reinforced plastic fabrications. Development of high temperature resins plus sophisticated reinforcement fiber orientation has made it possible for CTL to provide effective, low-weight fabrication —expansion cones of Minuteman, the nose of the Jupiter, the face of the Mercury. Find out how CTL can assist with your heat insulation problems. Request Bulletin 160.

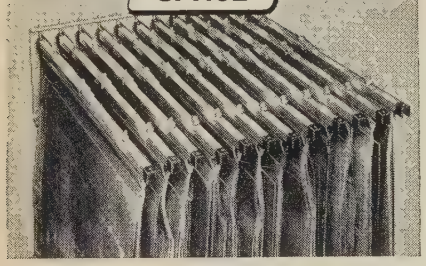
CTL 1241 GLENDALE-MILFORD ROAD, CINCINNATI 15, OHIO

A Division of Studebaker-Packard Corporation

Write in No. 208 on Reader Service Card at start of Product Preview Section

PLAN HOLD®
VERTICAL AND ROLL
Filing Systems
FOR PLANS, PRINTS, DRAWINGS

SAVE SPACE

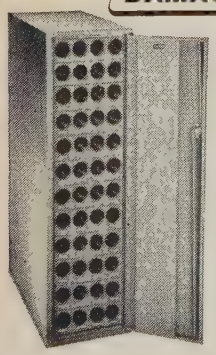


In only 24 lineal inches you can file up to 1200 large sheets. Rack easily mounted on any wall at height determined by length of sheets.

SPEED USE

When plans are used by 2 or more people or departments, the PLAN HOLD Rolling Stand is a great convenience. Glides on ball-bearing casters.

PREVENT DAMAGE



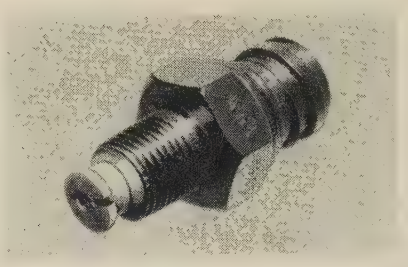
Steel cabinets in modular sizes give extra protection to valuable plans. This Combo Cabinet is equipped with 48 roll file tubes. Also available with vertical files for up to 1200 sheets.

PLAN HOLD equipment brings engineering efficiency to filing and use of all large sheets. Distributed nationally through engineering supply and office equipment dealers. Return coupon for illustrated catalog and prices.

PLAN HOLD CORPORATION
5204 Chakemco St., South Gate, Calif.
Please send catalog No. **602** I am interested in vertical ☐ or roll files ☐.
Your name_____
Company_____
Street_____
City_____ Zone____ State_____

Write in No. 209 on Reader Service Card

PROBES are threaded



Integral pipe threads for easy assembly into equipment are featured by three types of resistance temperature measuring probes, says **Ruge Associates, Inc., Dept. S/A, Hudson, N.H.** Two of the three have minimum protection for the temperature-sensitive winding to obtain a time constant of about 100 msec in liquids.

Applications include fluids, gases, or potting compounds not injurious to phenolics. The third unit has a stainless steel protective sheath to permit operation in corrosive fluids and under pressures up to 150 psi. Its time constant is two sec.

Write in No. 290 on Reader Service Card

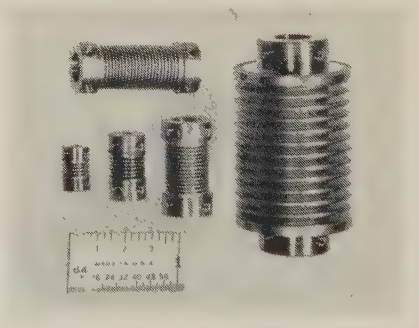
RF CABLE RECEPTACLE saves space

Type 3009 ConheX right angle bulkhead receptacle insures that a cable is within 3/16 in from the panel, says **Sealectro Corp., Dept. S/A, 139 Hoyt St., Mamaroneck, New York.**

The ConheX line of 50- and 75-ohm subminiature rf cable connectors meet the widest range of standard connector requirements.

Write in No. 291 on Reader Service Card

MINIATURE COUPLINGS are fully flexible



The thin-walled bellows of these miniature couplings contribute to the full flexibility evident in even the smallest sizes says **Servometer Corp., Dept. S/A, 222 Main Ave., Passaic, N.J.** The couplings are as small as 0.125 in od by 0.245 in long, and they are suitable for use in servos and computers.

Available torques range from 0.1 to 250 in oz. Side thrusts begin at one gram at .005 in offset, and twist angles are under 0.3 deg in all sizes.

Write in No. 292 on Reader Service Card

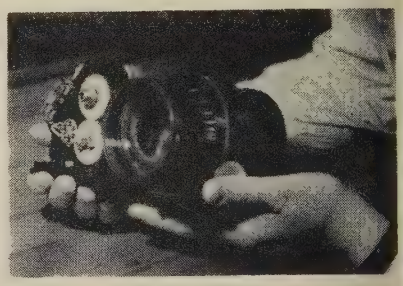
MAGNET WIRE is flexible, durable

Silicone-Teflon magnet wire with nickel-plated copper conductors, an organic film-coated magnet wire, is used in transformers, solenoids, miniature relays and motors. Experimental transformers were subjected to sufficient load to maintain an average conductor temperature of 250 deg C and operated continuously for 11,000 hours without failure, according to **Anaconda Wire & Cable Co., Dept. S/A, 25 Broadway, New York 4, N. Y.**

It is available in round sizes, No. 15 AWG through 36, in both single and heavy film thicknesses.

Write in No. 293 on Reader Service Card

HIGH SPEED LENS for CRT transfer



This high resolution 1:1 Transfer Lens is designed to afford optimum reproduction of cathode-ray signals. It has a relative aperature ranging from f/2 (at infinity) to f/22 and will cover a 4½ in diagonal format, says **Perkin-Elmer, Electro-Optical Div., Dept. S/A, Norwalk, Conn.**

Object-to-image distance is 17.6 in, Color correction is 4200A-5200A, optimized for P-11 phosphor. The unit measures 5 3/16 in long with a 3¾ in diam and weighs 3½ lb. Optional equipment includes a reflecting unit to bend the light path, and motorized remote control for adjustment of the lens iris.

Write in No. 294 on Reader Service Card

VANE PUMP for ground support

This vane pump is said to offer wide application on a variety of ordnance and ground support vehicles, such as special purpose tanks, missile launcher and erector vehicles, weapon carriers and tactical landing craft, according to **Vickers, Inc., Dept. S/A. 172 E. Aurora St., Waterbury 20, Conn.** All wear parts are contained in a cartridge which can be replaced in about ten minutes without removing pump from housing.

Interchangeable cartridges will deliver 52, 63, and 75 gpm at 2000 psi. At SAE rating, 1200 rpm, 100 psi, deliveries are 34, 41, and 48 gpm respectively.

Write in No. 295 on Reader Service Card

more on page 310

The only operational cartridge starter...

SPECIFICATIONS:	
Output shaft speed	3000 rpm (max)
Dry weight (not including cartridge)	60.0 lbs (approx)
CARTRIDGE STARTING	
Operating temp.	—65° to 160°F
Chamber pressure normal operation	850 psi
Safety plug diaphragm burst pressure	2000 psig (nominal)
Operating voltage	15 to 32 volts
PNEUMATIC STARTING	
Operating air pressure and temp.	50 psia and 350°F (nominal)
Operating air flow	100 lbs per min (approx)

AIRESEARCH'S CARTRIDGE/PNEUMATIC STARTER *has completed more than 20,000 successful cartridge starts for the F-100, F-105 and Hound Dog missile applications.*

ıpletely fail-safe, this lightweight pack- is the only cartridge starter capable ıll containment of a wheel hub burst. he AiResearch starter is extremely ble and compact, making it easily ɔted to any jet engine envelope. For ıple, the same starter now used on Hound Dog missile can be delivered ediately for use on the B-52 itself. iis self-contained, aircraft-installed ing system provides quick, dependable s in any climate or location by means of high temperature cartridge gases *or* low pressure air such as supplied by an AiResearch gas turbine serving as an onboard pneumatic power source or conventional ground support unit.

The starter consists, basically, of an air turbine starter and a removable solid propellant cartridge chamber. Combustion of the cartridge directs high pressure gas against the turbine wheel, turning the output shaft. Overspeed is controlled by aerodynamic braking action of air compressed by radial blades on the other side of the turbine wheel.

This simple system consists of proven components with many thousands of hours of successful operating history. The pioneer and leading manufacturer of air turbine starters of all types for both military and commercial application, AiResearch has more than four years of cartridge experience and 12 years' experience in pneumatic starters.

Your inquiries are invited.

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

Write in No. 210 on Reader Service Card at start of Product Preview Section

New...from MARSH!

Conduit-type Mastermite. Grommet-type also available.

Small Solenoid Valves that fill a BIG Order

Designed to meet the need for positive-acting tight-seating valves for use on wide variety of media, including oxygen, hydrogen, acetylene, etc.

Two Types:
Conduit type and grommet type. Port sizes 1/8" and 1/4" NPT.

Ten orifice sizes: 3/64" through 1/4".

Wide range of voltages:
Standard with 115 V. A. C. but also available in 12, 24, 208, 230, 460 V. A. C.

Pressure to 540 psi.
Small, but with more strength in the Marsh manner. Coils never overheat. Entire assembly leak tight. Remarkably quiet operation. Cleanable without breaking connections. Used in any position. Bodies either brass bar stock or 18-8 stainless steel. All moving parts stainless. Underwriters' approved for use on oxygen and hydrogen and as safety valves.

Write for new bulletin

MARSH INSTRUMENT COMPANY
Dept. 4-J, Skokie, Illinois
Division of Colorado Oil and Gas Corporation
Marsh Instrument & Valve Co., (Canada) Ltd., 8407 103rd St., Edmonton, Alberta, Canada, Houston Branch Plant, 1121 Rothwell St., Sect. 15, Houston, Texas.

Write in No. 221 on Reader Service Card at start of Product Preview Section

DIGITAL PROCESSORS

Our Tactical Systems Laboratory applies advanced techniques to the design and development of airborne and ground-based digital data processing systems. If you have at least 2 years of design, system integration, testing or production experience in digital systems, your talents may find application in the solution of our technical problems. Write to Mr. S. L. Hirsch.

LITTON INDUSTRIES Electronic Equipments Division
Beverly Hills, California

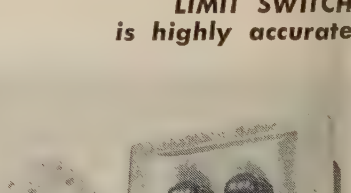
SMALL ACCELEROMETERS in single axis design

Small size, light weight, ruggedness, and sensitivity are features of the D1754-01 and D1756-01 single axis accelerometers, says **Kearfott Co., Inc., Dept. S/A, 1500 Main Ave., Clifton, N.J.** The design uses a spring mass system sensitive to linear accelerations along an input axis, but insensitive to those accelerations normal to that axis.

The units are reported to be ideally suited to missile inertial guidance applications because of their reliability in high-vibration environments. The D1754-01 is a Size 10 unit, and the D1756-01, a Size 22. The smaller has a calibration drift, measured in per cent per mo, of .15; that of the larger is .05. Voltage requirements, frequency and range (g) of both units are identical. Factory adjustments will remain substantially unaffected for about 10,000 hrs of operation.

Write in No. 307 on Reader Service Card

LIMIT SWITCH is highly accurate



This electronic limit switch senses and remotely limits position, weight, level or pressure. It is designed for applications where one or more trip-points must be frequently reset as in sequencing or programing. Limits are set quickly to accuracies of ⅛ of 1 per cent of full scale for standard units or to one part in 250,000 for special systems, says **Jordon Co. Inc., Dept. S/A, 3235 W. Hampton Ave., Milwaukee 9, Wisc.**

The unit is used for setting machine tool limits, for setting trip points on batch weighing scales or load cells, for adjusting pressure limiting devices and other position or load limiting functions.

Write in No. 308 on Reader Service Card

more on page 312

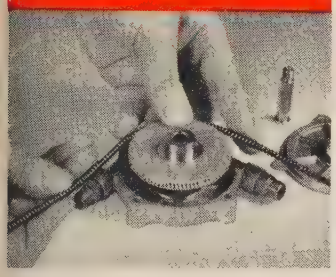
WHAT'S YOUR REMOTE CONTROL PROBLEM?

Here are six reasons why Teleflex can help you find the right solution!

1

High-temperature efficiency. New high-temperature alloys and lubricants combined with unique TELEFLEX helical cable design produce efficiencies and dependability not possible with any other type of remote control systems. At 1400 degrees, control operates at 90% to 97% efficiency around 90 degrees of bend. No special compensations needed for temperature variations within system.

2

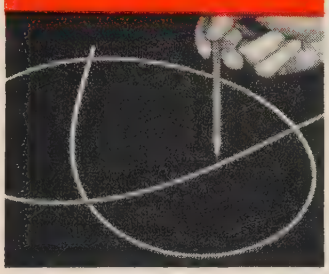


Accurate drive. Helical design of TELEFLEX cable engages with a specially hobbed wheel for positive drive in tension and compression. Result: unlimited shaft rotation in either direction—exclusively with TELEFLEX Systems!

3

Flexible installation. TELEFLEX Systems can be designed over, around, under obstructions without loss of extreme accuracy. Cable can be operated at 100 feet or more with minimum change in load characteristics.

4



Minimum space. TELEFLEX Systems weigh 54% to 60% less than comparable cable pulley, or rod and bell cranks; take only 1/9 as much space. No interference or leeway problem in your intricate units. Design into space that's left.

5

Expert design. TELEFLEX engineers are specialists in remote controls! Backed by an extensive research and development department, they can help you get around any remote control problem, no matter how advanced.

6

The record behind the "TELEFLEX Approach." Because there is no other cable like TELEFLEX, our engineers go beyond the point where all other systems come to a design stop—bring a new concept in the development and appreciation of remote control systems. Let us pit the "TELEFLEX Approach" against the problem you're working on now. Send for information today.

TELEFLEX® Incorporated, North Wales, Pennsylvania

Write in No. 214 on Reader Service Card at start of Product Preview Section

Latest high-temperature capacitor from AIRBORNE permits continuous duty at 700°F

STANDARD SIZES

STYLE A STYLE B STYLE C

PART No.	MFD	L	E	D	STYLE
E-8196-1M	.01	1.50	.625	625	A, B
-2M	.1	1.50	.875	.875	A, B, C
-3M	.25	.750	1.687	1.687	A, B, C
-4M	.5	1.625	1.437	2.00	A, B, C
-5M	1.0	1.625	2.125	2.125	A, B, C
-6M	2.0	1.625	2.750	2.750	A, B, C

Designed for integration with high-temperature aircraft/missile components, this newest addition to Airborne's line of miniaturized capacitors offers a working temperature range of –65 to +700°F—without voltage derating and with low capacitance variation.

As a dielectric for this new Airborne capacitor, we use a ribbon of thin, pure mica—because mica maintains its characteristics at temperatures well above 700°F. The conductor is aluminum foil, and the completed winding is encased in a stainless steel can for maximum corrosion resistance. A new copper spray technique has also been developed to provide high-temperature end connections. For terminals a special ceramic is used. These and other refinements provide the characteristics listed in the column opposite.

If you have requirements in high-temperature miniaturized capacitors, consult Airborne. Besides mica construction, we offer metallized Mylar* and Teflon† types—noted, as are all Airborne capacitors, for their electrical and mechanical reliability. Mylar is recommended to 300°F; Teflon to 400°F. Contact any of our offices or write for Product Bulletin PS-6A.

STANDARD CHARACTERISTICS—AIRBORNE HIGH-TEMPERATURE MICA CAPACITORS

Temperature: -65 to +700°F
Rated voltage: 300 VDC
Life: 250 hr. min. @ 340 VDC and 700°F
‡Capacitance tolerance: 10% Std.
Dissipation factor @ room temp.: 10,000 megohm/mfd @ 25°C

*Du Pont's TM for its polyester film
†Du Pont's TM for its tetrafluoroethylene resins
‡Closer tolerances on special order

AIRBORNE®

Engineered Equipment for Aircraft and Industry

AIRBORNE ACCESSORIES CORPORATION

HILLSIDE 5, NEW JERSEY • Offices in Los Angeles and Dallas

Write in No. 215 on Reader Service Card at start of Product Preview Section

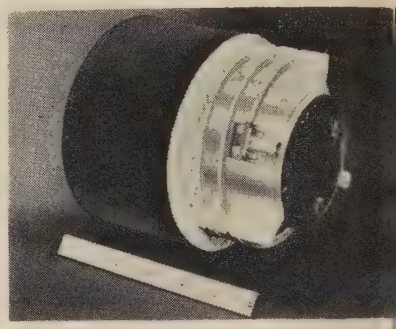
CERAMIC TRANSDUCERS for high temperatures

Development of a line of high temperature ceramic transducers capable of good performance up to 750 deg F has been announced by **Gulton Industries, Inc., Dept. S/A, 212 Durham Ave., Metuchen, N. J.**

The Glennite Hi-T piezoelectric ceramic transducer series, with the high Curie point of 750 deg F, are fabricated from ferroelectric materials—lead zirconate and lead titanate compounds—the maker says.

Write in No. 300 on Reader Service Card

DELAY LINES are compact, lightweight



These low-loss, wideband, compactly packaged microwave delay lines weigh only 25 oz and can replace more than 100 ft of coaxial cable. They unitize a construction technique employing a lightweight ceramic material with a high dielectric constant that will greatly reduce the total weight and cubic content of packaged units, says **Thompson Ramo Wooldridge Inc., Dept. S/A, P.O. Box 90534 Airport Station, Los Angeles 45, Calif.**

The S-Band Helical microwave delay line provides a time delay of 0.1 microsec for signals nominally in the 2.2 to 4.2 KM cps.

Write in No. 301 on Reader Service Card

BLOWER is efficient

The BR-36 refrigerated blower can maintain a preset temperature within from four to six completely equipped electronic cabinets, says **Western Devices, Inc., Dept. S/A, 600 W. Florance Ave., Inglewood 1, Calif.** The 6½-in-high unit may be preset to maintain cabinet temperature in the 60 to 100-deg F range, and it is factory set to hold a 70-deg temperature.

Capacity is 36,000 BTU. Heated air is drawn in at the top of the unit, cooled, and then recirculated by means of a plenum chamber connected to each of the cabinets. The blower reduces humidity and keeps dust from entering the cabinets.

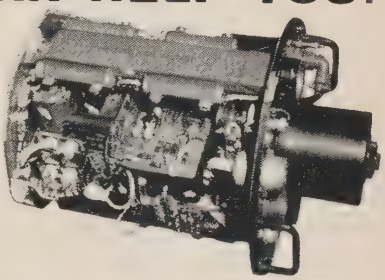
Write in No. 302 on Reader Service Card

more on page 314

"IN A STEW" OVER ELECTRONIC CONTROL?
UAP PACKAGING TECHNIQUES CAN HELP YOU!

You are encouraged to contact UAP at the very outset of projects involving electronic control. Concurrent with your overall design of the electronic package, UAP engineers will apply their specialized capabilities to specific problems involving *temperature, mechanical* or *mass flow* control. Cited below is a successful defense project involving concurrent UAP-customer teamwork.

UAP supplied Hazeltine Corporation, one of the nation's large defense contractors, with 13″ x 10″ cold plates for center-mounting within electronic guidance equipment. Areas were provided so small components could be mounted to the cold plate surface between larger power units. The cold plate dissipates 570 watts from varying heat concentration areas. Cold plate temperature does not exceed 173° F., with plate air-in temperature of 150° F. This permits use of less expensive electronic components. The entire package is contained in a UAP pressurized case.

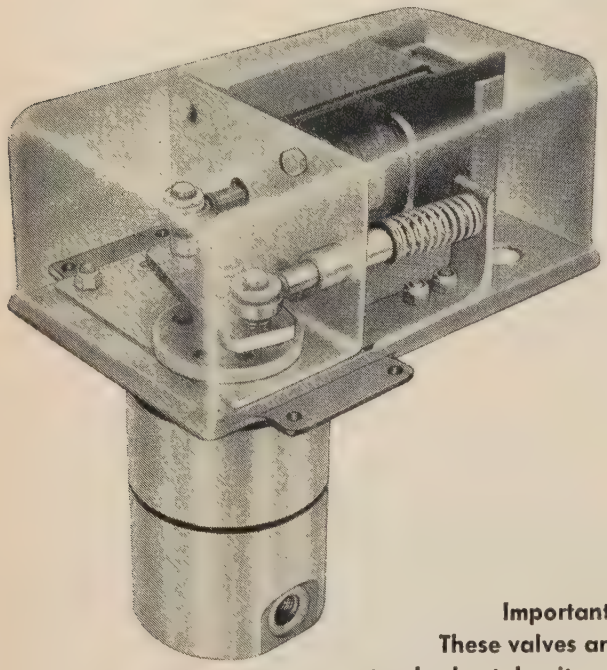


U-522277 Forced Air Cooling System

UAP can meet your requirements too! Send them to:
UNITED AIRCRAFT PRODUCTS, INC., Dayton, Ohio
(Contractual Engineering Offices: California, Gardena FA 1-4810; New York City MU 7-1283; Dayton, Ohio BA 4-3841; Canada, Montreal OX 7-0810)
WESTERN DIVISION, UAP, INC., Box 20, Gardena, California
Exporter: New York City, MU 9-6126, Cable ALLIED INTER

Write in No. 216 on Reader Service Card at start of Product Preview Section

10,000 P.S.I. SOLENOID VALVES



Important: These valves are standard catalog items.

● They are available for immediate delivery (in stock) at standard valve prices, for a service which generally requires costly (made-to-order) special valves.

● Shut off and 4-way valves in ¼, ⅜ and ½ inch port sizes are rated for 10,000 P.S.I. liquid or gases. They will withstand surges of up to 15,000 P.S.I. without damage to the valves' sealing qualities (designed for a burst pressure of 30,000 P.S.I.).
Solenoids are available for 115, 230 and 460 volt A.C. operation.

● Long maintenance-free service is achieved through the leak-proof "Shear-Seal" design. Optically flat metal to metal sealing surfaces (of the self-aligning sealing rings and the mating rotor face) are protected by staying in constant intimate contact: flow is always through the center of the "Shear-Seals," never across sealing surfaces. Sealing qualities actually improve as the seals lap themselves to a more perfect fit with each valve operation. There is no external shaft leakage because the pressure is confined to the flow passages.

For complete data write for catalog S-10000.

CONTROL VALVE DIVISION
barksdale valves

5125 ALCOA AVENUE • LOS ANGELES 58 • CALIFORNIA
Write in No. 217 on Reader Service Card

PANEL RECEPTACLE for quick connection

Rapid assembly into any electrical panel and quick connect and disconnect of wires are afforded by the Model WA-014, a receptacle with mating plug, according to **Cam-Lok Div., Empire Products, Inc., Dept. S/A, P.O. Box 98, Cincinnati 36, O.** The ⅞-in long unit can be mounted without special tools and is knurled to prevent rotation when pressed into a panel or insulating strip.

A threaded stud is provided for fastening to the power source terminal lug. Plug and receptacle make a positive locking conection with a high-pressure contact to eliminate accidental uncoupling. The receptacle can be used for #10 through #18 wire.

Write in No. 303 on Reader Service Card

VIBRATION ANALYZER in portable design

Measurement of peak-to-peak displacement and frequency of mechanical vibrations on jet and turboprop engines, motors and generators is possible with a portable vibration analyzer that weighs under 40 lbs, says **Aeronautical-Instrument Div., Sun Electric Corp., Dept. S/A, Harlem & Avondale, Chicago 31, Ill.** Measurements are made within specified milli-inch bands.

The Model PVA has four velocity-type seismic pickups with a flat frequency response of 20 to 2000 cps. Pickup sensitivity is rated at 21.4/mv/.001 in DA per 100 cps into a 20K load. The pickups are calibrated to one per cent accuracy. Power supply for the analyzer is a 12-V, 1.7 amp/hr nickel-cadmium battery, and it has a self-contained charging system.

Write in No. 304 on Reader Service Card

LIQUID SPRING produces high force

A 40,000-lb force on a ¼-in stroke can be achieved by the Model 2040 Liquid Spring, a self-contained package measuring 2½ in in dia and five in in length, says **Taylor Devices, Inc., Dept. S/A, 188 Main St., North Tonawanda, N.Y.** The design of the Model 2040 permits the addition of interior shock absorber action without change in the overall dimensions, and the shock absorbing force is available up to 60,000 lbs.

Applications include use as a yieldable member on overload applications in, for example, heavy press operations and as a yieldable force means for thermal expansion elements. Standard mounting is by a stud one in long, but other available mountings include pin eyes, clevises, or trunnions.

Write in No. 305 on Reader Service Card

TRANSFER PUMPS for cryogenic use

Continuous or intermittent duty from ten to 8000-gpm capacity with differential pressures up to 300-psi outlet can be attained by the Series 3000 petrochemical and cryogenic transfer pumps, says **Turbocraft, Inc., Dept. S/A, 492 E. Union St., Pasadena, Calif.** Design features include the minimum wet end weight to reduce cool-down time and minimize loss of liquid, the reduction of hazardous collection of gas in the pump area, and use of a thermal barrier between pump and motor.

The pumps are supplied close-coupled to an electric motor drive, but bearing housings are available to permit direct coupling to other drives, such as steam or gas turbines, and hydraulic motors. The devices operate at low values of net positive suction head. Advantages include minimum maintenance, easy removal from the system, and horizontal or vertical mounting.

Write in No. 306 on Reader Service Card

more on page 31

Write in No 218 on Reader Service Card

The most precise, sturdiest thermal relay ever built... best for missile applications

. from the leader in thermal relay design!

w, for missile environments and for all applications where greater precision is necessary, G-V Controls ers the revolutionary new PT Thermal Relay—the most **precise** thermal relay ever built!

d the PT's **sturdiness** is unequalled in thermal relays. It withstands missile vibration and shock far ter than any other thermal relay.

SPECIFICATIONS

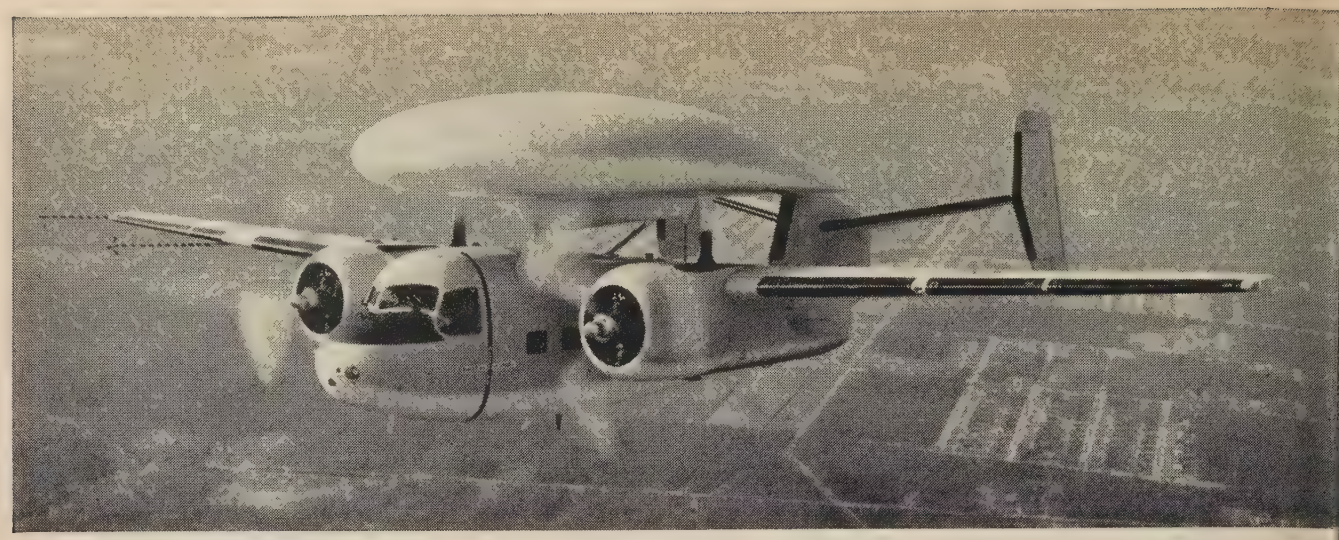
Time Delay: 3 to 60 seconds (Factory Set)
Setting Tolerance: ±5% (±¼ sec. min.)
Temperature Compensation: Within ±5% over −65°C. to +125°C. range (±¼ sec. min.)
Heater Voltages: 6.3 to 115 v. for delays up to 12 sec.; 6.3 to 230 v. for longer delays.
Power Input: 4 watts. Rated for continuous energization at 125°C.
Contacts: SPST, normally open or normally closed. Rated 2 amps. resistive at 115 v. AC or 28 v. DC.

Write for Product Data Bulletin #PD-1015

Insulation Resistance: 1,000 megohms
Dielectric Strength: 1000 v. RMS at sea level. 500 v. RMS at 70,000 ft.
Vibration: Operating or non-operating, 20 g up to 2000 cps
Shock: Operating or non-operating, 50 g for 11 milliseconds
Unidirectional Acceleration: 10 g in any direction changes delay by less than 5%, 50 g by less than 10% with proper orientation.
Weight: 2 to 2¼ ounces.

G-V CONTROLS INC.
Livingston, New Jersey

G-V®



GRUMMAN'S "SAUCER-TOPPED" WF-2 TRACER, early-warning airplane for Navy carrier operation, carries long-range radar detection equipment.

BENDIX 20 KVA GENERATING SYSTEM PROVES TREMENDOUS VERSATILITY

Here is a lightweight, transistorized, AC generating system that brings extreme dependability to its many applications. First developed for the USAF for one of its Century series fighters, the Bendix 20 KVA system will soon be flying for the U.S. Navy on Grumman's WF-2 and Sikorsky's HSS-2.

The Bendix system regulator will provide close voltage regulation and will hold transients to a minimum with rapid recovery. The protection panel will protect the critical aircraft components from under- and over-voltage and from under- and over-frequency.

Offers unusual effectiveness on missiles and on a wide variety of aircraft—in fact can be used on any engine-driven, air-driven, hydraulic-driven or pneumatic-driven application . . . either airborne or ground. Get further details from BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

West Coast Office: 117 E. Providencia, Burbank, Calif.
Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.
Canadian Affiliate: Aviation Electric, Ltd., P. O. Box 6102, Montreal, Quebec.

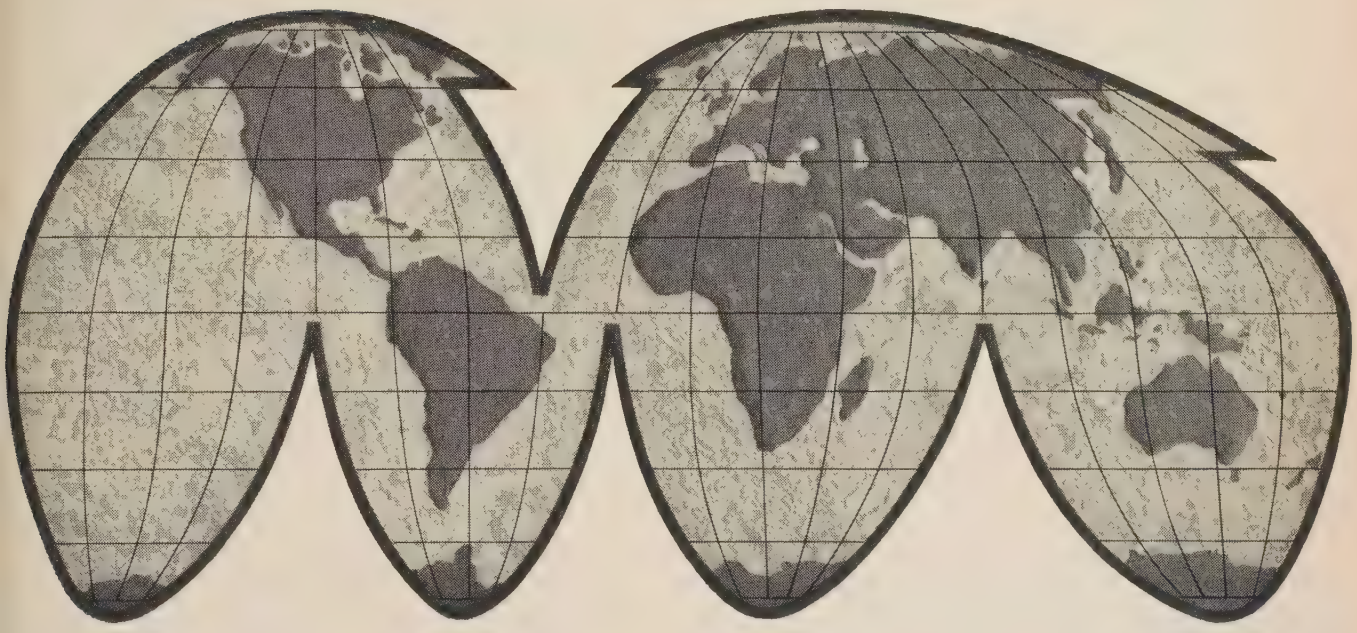
Red Bank Division — Bendix AVIATION CORPORATION

SIKORSKY HSS-2, designed for long over-water flight and low-altitude hovering—even alighting on water—during sonar anti-submarine missions.

Write in No. 219 on Reader Service Card at start of Product Preview Section

PACKAGED POWER

for Ground Support Needs Anywhere on Earth



PRECISION PORTABLE POWER — air transportable to any point on the globe in a few short hours. Minutes after delivery, American Electronics' mobile generating equipment is in operation serving outposts of the nation's defense network. Compact, rugged, dependable, these motor-, gas engine-, or diesel-driven power packs operate under the extremes of severe climatic conditions. Where the maximum in dependability and mobility in all environments is required . . . where prompt ground and air transportability means the difference between success and failure, you'll find the Packaged Power products of American Electronics' Ground Support Division doing the exacting job.

Write for brochure detailing full particulars

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GROUND SUPPORT DIVISION

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PRODUCERS OF PORTABLE POWER • AIR CONDITIONING • MECHANICAL SUPPORT • ELECTRONIC SUPPORT • GROUND SUPPORT SYSTEMS

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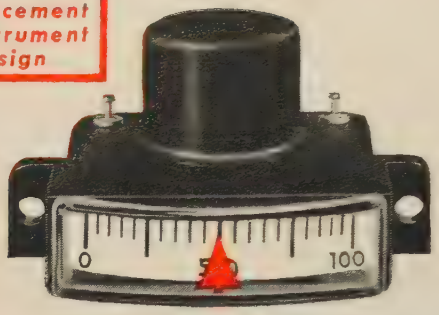
marion
advancement in instrument design



EDGEWISE METER

Large, easily read display (1 7/16" scale) in only 9/16" x 1 7/8" panel space. For horizontal or vertical mounting. Miniature, self-shielded Coaxial mechanism has stability and durability of larger instruments. Weight 1.7 oz. Supplied with combination mounting bracket and bezel (not shown). Data on request. Marion Instrument Division, Minneapolis-Honeywell Regulator Co., Manchester, New Hampshire, U.S.A. *In Canada, Honeywell Controls Limited, Toronto 17, Ontario.*

Honeywell

75th YEAR PIONEERING THE FUTURE First in Control SINCE 1885

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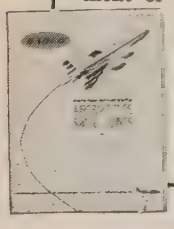
NOW AIRCRAFT TYPE SWIVEL JOINTS

LOW TORQUE PLANE SWIVEL JOINT— 360° rotation in a single fixed plane.

NEW SELF-ALIGNING SWIVEL JOINT— 360° rotation *plus* 15° side flexibility.

BARCO Offers Two Standard Types

Here are the newest designs in the field! SEND TODAY FOR BARCO CATALOG 269A. Since 1941 Barco Swivel Joints and special Flexible Assemblies have met the precise requirements of in-flight and other types of military equipment . . . *conforming to MIL-J-5513A and other specifications.* Barco's wide experience is yours to call upon in the development of your particular project — aircraft, missile, track vehicle or special installation — for hydraulic, pneumatic, oxygen, fuel, gas or liquid service. Barco Representatives are at your service in the specification of standard or specialized adaptations of standard designs.



BARCO MANUFACTURING CO.
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Serving Industry Since 1908

Write in No. 213 on Reader Service Card

TRANSDUCER for low pressures

Infinite resolution output is designed into the Model 155 pressure transducer, a device that has resolved the problem of dynamic performance of pressure instrumentation at the zero to plus or minus one psi level, says American Machine and Metals Co., Dept. S/A, 65 Rushmore St., Westbury, N. Y. Performance holds at higher ranges where an unbonded type sensor is used as the prime mover.

The device provides vibrational g loadings from zero to 25 g's in all axes in the range scale from zero to plus or minus one psi and from zero to 150 psi. Maximum errors, including all resonant points, are two per cent or less. Use of a conductive plastic resistor instead of wire wound potentiometers contributes to the Model 155's excellent characteristics.

Write in No. 296 on Reader Service Card

CONNECTORS for high altitudes

Stainless steel shells and precision-molded sealing gaskets are used in these miniature rectangular environmental connectors, which have been tested up to 200,000 ft, says AirBorne Connectors, Inc., Dept. S/A, 2615 Manana Drive, Dallas, Texas. The connectors exceed the requirements of MIL-C-8384 and mate with existing MS types under this specification.

Other features include high-strength, glass-fiber-filled jackscrews and closed entry beryllium copper contacts. The connectors are available with up to 104 contacts.

Write in No. 297 on Reader Service Card

DISPLAY SYSTEM is automatic

Two- and three-dimensional Iconorama systems display on any size screen in any color marking information simultaneously from any number of targets. Alphanumeric identification symbols are generated and displayed automatically for each track, says Fenske, Fedrick and Miller, Inc., Dept. S/A, 12820 Panama St., Los Angeles 66, Calif.

Utilizing existing telephonic or teletype circuits permits uncomplicated methods of transmission and reception of the visual data.

Write in No. 298 on Reader Service Card

HOT GAS COMPONENTS for missile servo systems

A lightweight hydrazine reaction chamber and a solid propellant hot gas filter are among six small components developed for missile and space vehicle hot gas servo systems, according to Chandler Evans Corp., Dept. SA, West Hartford 1, Conn. The high pressure units may be used in such applications as auxiliary and control power systems.

The 1.27-lb chamber has an operating temperature to 1800 deg F and an operating pressure to 2000 psi. Flow capacity is .10 lb/sec, and operating time is over five hrs. The hot gas filter, which can easily be cleaned for re-use, can filter out ten-micron particles, and initial pressure drop at .015 lb/sec is two psi at 1000 psi. The other components are: a reed-suspended closed center servo valve, rated for an inlet gas pressure to 2000 psi, for use with hot gas produced by decomposition of liquid propellants; a spark-loaded, spool-type propellant-flow modulating and pressure regulating valve equipped with an adjustment screw for pressure changes over the 500 to 2000-psi range; a hot gas pressure relief valve with relief pressure adjustable from 800 to 1200 psi; and a hot gas laboratory reaction chamber designed to provide clean, hot, high-pressure gas for test purposes. This test chamber uses flow rates between .001 and .1 lb/sec.

Write in No. 299 on Reader Service Card

more on page 32

Official United States Navy Photograph

Sparrow III Navy air-to-air missile is now operational with both the Sixth and Seventh Fleets. Raytheon is prime contractor for this potent weapon.

RAYTHEON COMPANY, WALTHAM, MASS.

RAYTHEON

EXCELLENCE IN ELECTRONICS

SOUTHWEST
"Monoball"®
SELF-ALIGNING
BEARINGS

ROD END
TYPES

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PLAIN TYPES

CHARACTERISTICS

	ANALYSIS	RECOMMENDED USE
1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Alloy Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Steel Ball	For types operating under normal loads with minimum friction requirements.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. Write for Engineering Manual No. 551. Address Dept. S/A 60.

SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

Write in No. 222 on Reader Service Card

SPECTRUM ANALYZE
are transistoriz

This series of spectrum analyzers reduce band-width
quirements for airborne telemetry applications. The u
available in three miniature models, will analyze ei
acoustic or high frequency vibration data signals with
ings in transmission bandwidth of up to 1000 times acc
ing to **Gulton Industries, Inc., Ortholog Div., Dept. S
212 Durham Ave, Metuchen, N.J.**

Compatible for use with existing IRIG telemetry syste
the three models cover operating frequency ranges f
25 to 10000 cps, bandwidth resolutions of 20, 95 or
cps and a sweep linearity of ±1 per cent.

Write in No. 309 on Reader Service Card

ROTARY SELECT
controls automatic equipm

This variable programing circuit controls and char
the sequence of functions in automatic equipment.
circuit employs a Ledex Rotary Selector that uses an
verse-homing, tab-type control-wafer switch, says **G.
Leland, Inc., Dept. S/A, 123 Webster St., Dayton 2, O**

The control wafer in conjunction with a hold-in resi
will cause the selector, when impulsed, to skip over
wanted positions.

Write in No. 310 on Reader Service Card

LOW-PASS FILT
feature sharp cu

These low-pass filters also feature low insertion loss
low VSWR. Attenuation beyond cutoff is guaranteed 5
over most of the range, says **Narda Microwave Corp., L
S/A, 118-160 Herricks Rd., Mineola, N.Y.**

The insertion loss is 1 db maximum and low VSW
the pass band 1.5 maximum. Units are available for
quencies of 500, 1000, 2100, and 4200 mc.

Write in No. 311 on Reader Service Card

AMPLI
for telemetry

Model PA-10 amplifier is used to amplify to 10 w
signal of any 2 w transmitter. Unit withstands oper
temperatures up to 200 deg F, vibration of 20 g, 2
2000 cps, acceleration of 10 g, and shock of 120 g,
**United Electrodynamics, Dept. S/A, 200 Allendale
Pasadena, Calif.**

A hermetically sealed amplifier, it operates at all altit
and exceeds Mil specifications for salt spray and dust.
amplifier weighs only 9 oz and measures 2 x 1 9/16 x

Write in No. 312 on Reader Service Card

ACCELEROM
for severe environm

The TA-400 accelerometer will accurately measure l
acceleration in missiles and aircraft under severe shock
vibration conditions, says **Components Div., Fairchild
trols Corp., Dept. S/A, 225 Park Ave., Hicksville, N.Y.**
15/16-in diameter unit, believed to be the smallest
type in production, will withstand 100-g shock and
vibration over 50 to 20,000 cps.

Provisions are included for a superimposed dc
excitation on the pick-off, and excitation torques the
off and pendulum in either direction from null. The
torquing feature permits the instrument to be checke
without moving the missile or aircraft. The unda
natural frequency extends from ten to 175 cps,
weight of the unit is under 2.5 oz.

Write in No. 313 on Reader Service Card

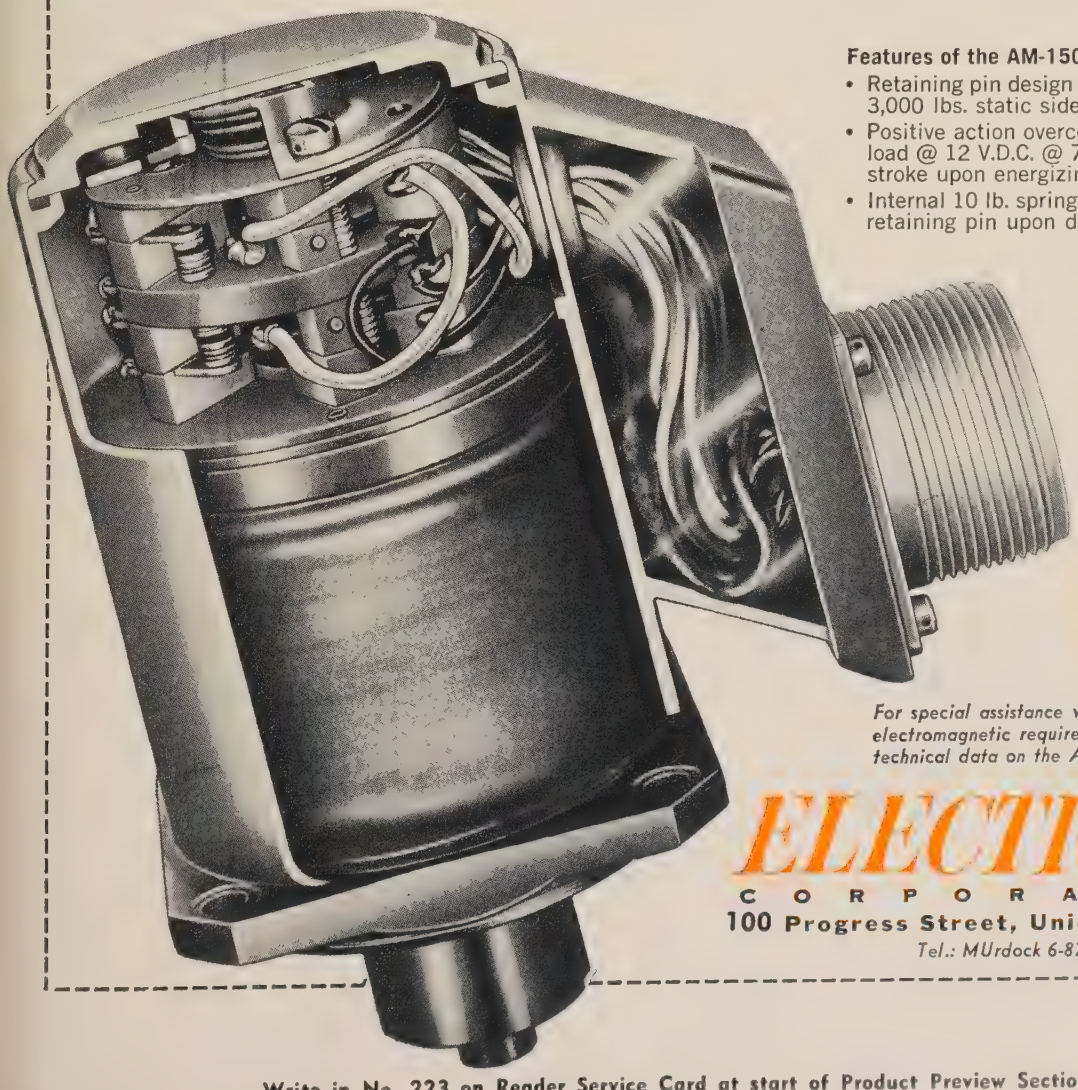
more on pag

Unique Electromechanical Interlock Performs Multiple Switching and Signalling Functions...

Fail-Safe Feature: Retaining pin design withstands 3,000 lbs. static side force

ELECTROID's model AM-1500 represents an entirely new concept in solenoid relay design, capable of mechanically retaining extremely high loads and simultaneously providing electrical interlock and positioning information. Switches can be set precisely to any predetermined operating tolerance. Various arrangements of independent interval SPDT switches can be operated at both the beginning and end of stroke.

This feature, by either internal or external electrical connection of the switches, can be made to interlock remote mechanical or electrical action. Provides high shock and vibration resistance (meets MIL-S-7029, MIL-E-5272 and MIL-S-4040 specifications). Fail-safe feature for aircraft, missiles and missile launchers.



Features of the AM-1500 (as illustrated)

- Retaining pin design withstands 3,000 lbs. static side force.
- Positive action overcomes 15 lbs. load @ 12 V.D.C. @ 72° F @ .250 stroke upon energizing.
- Internal 10 lb. spring force repositions retaining pin upon deenergizing.

For special assistance with your particular electromagnetic requirements and for complete technical data on the AM-1500, write today.

ELECTROID

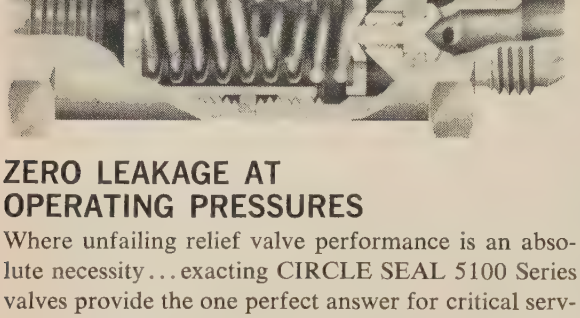
CORPORATION

100 Progress Street, Union, New Jersey

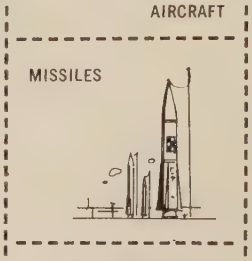
Tel.: MUrdock 6-8290

Write in No. 223 on Reader Service Card at start of Product Preview Section

CIRCLE SEAL RELIEF VALVES *for...*

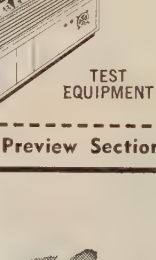


CLOSED PRESSURIZED SYSTEMS



AIRCRAFT

MISSILES



TEST EQUIPMENT

ZERO LEAKAGE AT OPERATING PRESSURES

Where unfailing relief valve performance is an absolute necessity... exacting CIRCLE SEAL 5100 Series valves provide the one perfect answer for critical service requirements. Each valve incorporates the scientific principles and exacting manufacturing methods that have made Circle Seal valves superior examples of the valve maker's art. Each Circle Seal 5100 Series valve offers these advantages: **• Zero Leakage • Dead Tight Reseat • Minimum Pressure Rise During Opening • Excellent Flow Characteristics • Tamper-Proof But Adjustable Settings • No Chatter Or Squeal • Maintenance-Free Service Life.**

CIRCLE SEAL® *precision valves*

Write for free engineering data.

JAMES, POND & CLARK, INC.
2181 East Foothill Blvd., Pasadena, Calif.

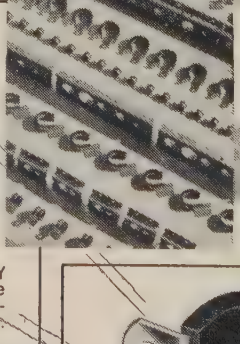
Write in No. 224 on Reader Service Card at start of Product Preview Section

ADEL LINE SUPPORTS

designed for every application

CLAMPS · BLOCKS · HARNESS STRAPS

for military & industrial systems & equipments



They cut maintenance and replacement costs ... performance and reliability far beyond specifications of any other Line Support.

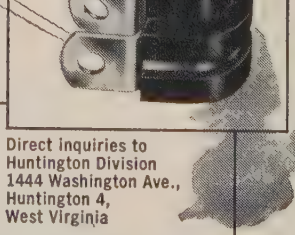
CLAMPS provide cushioned, vibration absorbing support for cables, tubing and piping.

BLOCKS provide resilient support for multiple grouping of lines to eliminate failures.

HARNESS STRAPS embody heat and cold resistant material for temperatures far above +550°F to well below −90°F.

For safety, flexibility, durability and economy SPECIFY ADEL and be certain of getting the best possible service from products that are the result of advanced engineering design and the most modern production techniques.

A COMPLETE LINE ... SERVICE-FITTED, TESTED AND APPROVED. SPECIFICATIONS ARE AVAILABLE TO AIRCRAFT, MISSILE AND ORIGINAL EQUIPMENT MANUFACTURERS ... WHAT ARE YOUR REQUIREMENTS?



Reliability

ADEL PRECISION PRODUCTS

A DIVISION OF GENERAL METALS CORPORATION

DISTRICT OFFICES: Burbank • Minneola • Dayton • Wichita • Dallas • Toronto

Direct inquiries to Huntington Division 1444 Washington Ave., Huntington 4, West Virginia

Write in No. 225 on Reader Service Card at start of Product Preview Section

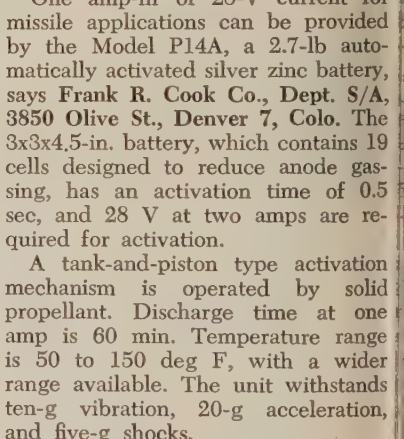
VERTICAL GYROSCOPE is completely self-contained

Model NV3705 is a two axis, torquer erected vertical gyroscope designed for use in aircraft and missile applications. Vertical reference is obtained by sensitive electrolytic switches and pitch and roll displacements are referenced by synchro pick-offs on the gyro axis, says **Iron Fireman Mfg. Co., Electronics Div., Dept. S/A, 2838 S.E. Ninth Ave, Portland 2, Ore.**

Constructed of non-magnetic cast stainless steel, the unit has symmetry of design in all parts and a center of gravity mounting to withstand high level shock and vibration.

Write in No. 314 on Reader Service Card

BATTERY activates very quickly



One amp-hr of 28-V current for missile applications can be provided by the Model P14A, a 2.7-lb automatically activated silver zinc battery, says **Frank R. Cook Co., Dept. S/A, 3850 Olive St., Denver 7, Colo.** The 3x3x4.5-in. battery, which contains 19 cells designed to reduce anode gassing, has an activation time of 0.5 sec, and 28 V at two amps are required for activation.

A tank-and-piston type activation mechanism is operated by solid propellant. Discharge time at one amp is 60 min. Temperature range is 50 to 150 deg F, with a wider range available. The unit withstands ten-g vibration, 20-g acceleration, and five-g shocks.

Write in No. 315 on Reader Service Card

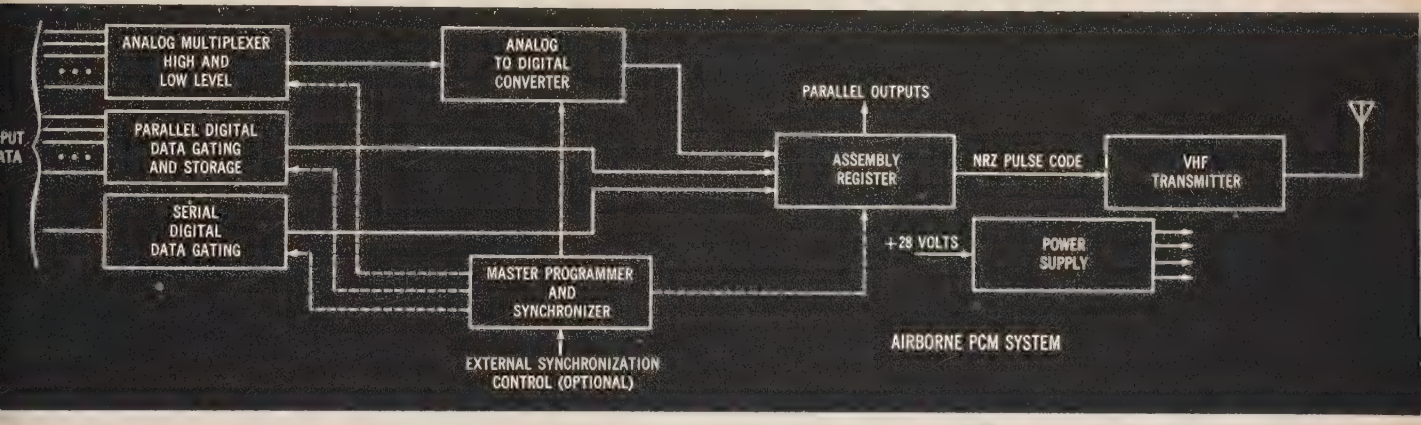
BAND PASS FILTERS are miniature

Type TBP filters cover the frequency range from 200 Mcps to 2400 Mcps. Bandpass may be set at any value between 5 and 25 per cent. Sections may be varied from 2 to 4 with an insertion loss of 0.5 ±0.2 db per section, says **Telonic Engineering Corp., Dept. S/A, Laguna Beach, Calif.**

The electrical performance of the filters corresponds to resonant cavities or tank circuits gaving unloaded Q's of over 200. Diameter of the units is only slightly over that of the BNC connectors at each end.

Write in No. 316 on Reader Service Card

NEW FROM TEXAS INSTRUMENTS!



High capacity, ½ cu ft, PCM telemetry system ..with system drift nulled out!

ow you can get the benefits of digital techniques accuracy, speed and reliability — in compact pulse de modulation telemetry systems from Texas Instruents. The 25-pound, ½ cubic foot package shown es only solid state devices, and may be used to drive y of the compact TI transmitters dictated by the plication. The system multiplexes and encodes 64 alog channels; and processes five 8-bit parallel gital data channels plus a serial digital data channel a nominal bit rate of 200 kc.

A key feature of the system is its high-speed analog ltiplexer which handles low- and high-level data, a combination of both, with *only a single low-level amplifier.* Overall accuracy of the system is ±0.25% — made possible by a unique bi-directional servo loop that nulls out system drift. The system is packaged in individual modules so that it can be rapidly modified to fit the needs of other missiles or space vehicles.

PCM is only one of several advanced telemetry projects at Texas Instruments. Others include the development and/or production of analog systems and equipments for Bomarc, Corvus, Pershing, Minuteman, Titan, Centaur, and Project Mercury.

For detailed information about PCM telemetry or other TI missile electronic system capabilities, please contact SERVICE ENGINEERING:

TEXAS INSTRUMENTS
INCORPORATED
APPARATUS DIVISION
6000 LEMMON AVENUE
DALLAS 9, TEXAS

Write in No. 226 on Reader Service Card at start of Product Preview Section

data preview

RECORDERS—Bulletin GEA-6933 (12 pages, two color) provides buying information on complete line of recording instruments, manufactured by **General Electric Co., Dept. S/A, Schenectady 5, N.Y.** Dimensions and chart speeds, operating specifications, applications, features and accessories are included.

Write in No. 317 on Reader Service Card

FACILITIES—A descriptive brochure outlining their capabilities for research and production in the field of electro-magnetic interference reduction and control is available from **Filtron Company, Inc., Systems Div., Dept. S/A, 10023 W. Jefferson Blvd. Culver City, Calif.**

Write in No. 318 on Reader Service Card

RECTIFIER CONTROLS — Bulletin MRC 658 describes a line of smaller and lighter magnetic rectifier controls manufactured by **Fairfield Engineering Corp., Dept. S/A, 934 Hope St., Springdale, Conn.** The bulletin has schematic diagrams and describes the operation of many magnetic rectifier control applications.

Write in No. 319 on Reader Service Card

CHECKOUT EQUIPMENT—An illustrated catalog sheet describes in detail "DEMON" the universal digital automatic checkout equipment manufactured by **Curtiss-Wright Corp., Dept. S/A, 6767 Hollister Ave., Goleta, Calif.**

Write in No. 320 on Reader Service Card

TRANSDUCERS — An eight page, three color Short Form Catalog describing their entire line is now available from **George L. Nankervis Co., Cox Instruments Div., Dept. S/A, 15300 Fullerton, Detroit 27, Michigan.** The line consists of a wide variety of flow measuring transducers, associated electronic readout equipment and flow calibrating devices.

Write in No. 321 on Reader Service Card

SUBMINIATURE FUSES — Complete technical information on Microfuse subminiature fuses is contained in a catalog page available from **Littlefuse, Inc., Dept. S/A, 1865 Miner St., Des Plaines, Ill.** The units, ideal for printed circuits, feature close resistance tolerances, and they are available in 1/500 to five-amp ratings for circuit voltages up to 125 V.

Write in No. 322 on Reader Service Card

GAGE—Bulletin 1621 describes the Type 5-050 Dynamic Tape Tension Gage manufactured by **Consolidated Electrodynamics Corp., Data Tape Div., Dept. S/A, 360 Sierra Madre Villa, Pasadena, Calif.**

Write in No. 323 on Reader Service Card

ELECTROMECHANICAL DEVICES — Handbook No. 358 contains detailed descriptions of the precision speed reducers and gear heads, counting devices, servo packages, and electromechanical assemblies manufactured by **Bowmar Inst. Corp., Dept. S/A, 8000 Bluffton Rd., Fort Wayne, Ind.** Specialized technical material compiled by the engineering staff is also included.

Write in No. 324 on Reader Service Card

WIRE & CABLE—Listed in catalog 1-59 is a variety of the most wanted wire and cable items manufactured by **Alpha Wire Corp., Dept. S/A, 200 Varick St., New York 14, N.Y.** In addition complete coverage of Alphlex Tubing as well as lacing cord and tape may be found.

Write in No. 325 on Reader Service Card

MICROWAVE INSTRUMENTS — An 120 page catalog containing detailed information on slotted lines, impedance plotters, adjustable matching networks and other microwave equipment is available from **Alford Mfg. Co., Dept. S/A, 1299 Atlantic Ave., Boston 10, Mass.** In addition to technical descriptions, pictures, diagrams, the catalog includes complete price lists and ordering information.

Write in No. 326 on Reader Service Card

CONTROL SYSTEMS — Modular control packages consisting of standardized control boxes are described in bulletin PS-5A offered by **Airborne Accessories Corp., Dept. S/A, 1414 Chestnut Ave., Hillside 5, N.J.** Systems include transducer, preamplifier, power amplifier, linear or rotary actuator plus auxiliary equipment as required.

Write in No. 327 oa Reader Service Card

REGULATING VALVES—Engineering Bulletin A-300, a four-page publication describing cartridge style, pressure-compensated, hydraulic flow regulating valves for aircraft, missile and ground-support systems, is available from **Waterman Engineering Co., Dept. S/A, Box 391, Evanston, Ill.** The valves are suitable for pressures to 3000 psi.

Write in No. 328 on Reader Service Card

CRYSTAL GROWTH — Single-crystal YIG growth is described in a bulletin offered by **Linde Co., Dept. S/A, 30 E. 42nd St., New York 17, N.Y.** The publication is entitled "Growth of Single Crystals of Incongruently Melting Yttrium Iron Garnet by the Flame Fusion Process."

Write in No. 329 on Reader Service Card

REFLEX KLYSTRONS—A 4-page catalog on reflex klystrons and Rocket planar triodes has been made available by **Sylvania Electric Products Inc., Dept. S/A, 1100 Main St., Buffalo, N. Y.** Principal electrical characteristics for 22 klystron types and nine planar triodes are listed.

Write in No. 330 on Reader Service Card

SEPARATION SYSTEM—A thorough description of a system for the synchronized separating of components at two or more points has been presented in the eight-page Bulletin CFSS by **Camloc Fastener Corp., Dept. S/A, 22 Spring Valley Rd., Paramus, N.J.** The Controlled Forces Separation System is suggested for the separation or release of missile stages and booster pads, fueling connections, umbilical missile connections, escape capsules, and aircraft cargo.

Write in No. 331 on Reader Service Card

REFERENCE GYRO—Complete information on the Master Reference Gyro MK 1, which provides accurate attitude information in all flight conditions, has been presented in a 16-page booklet published by **S. G. Brown, Ltd., Dept. S/A, Shakespeare St., Watford, Hertfordshire, England.** The flight instrument can replace the conventional artifical horizon gyromagnetic compass, and directional gyro, and it provides attitude and azimuth reference to other systems.

Write in No. 332 on Reader Service Card

PIVOTS—A line of small-size, very accurate universal flexure pivots has been described in a 12-page bulletin available from **Aeroscience, Inc., Dept. S/A, 3155 N. Rosemead Blvd., Rosemead, Calif.** Available in load capacity ranges from zero to 1,500,000 lbs, the pivots suit many applications, including high-precision calibration systems and thrust stands, missile static and dynamic test fixtures, fatigue machines, and universal drive shafts.

Write in No. 333 on Reader Service Card

more on page 326

Write in No. 227 on Reader Service Card➡

ENGINEERING OBJECTIVITY..On Mark Engineers are frequently confronted with a "square peg-round hole" situation, developing couplings for the ever more demanding requirements of the space age. Their answer: "engineering objectivity," the ability to seek beyond the state of the art. Valving, flexibility, method of disconnect...drastic environmental situation...liquid air or gas...each problem gives way to the On Mark approach. For this reason, On Mark couplings play a leading part in the Titan, Atlas, Discoverer, Jupiter, Polaris, Redstone, Mace and other missile systems. This specialized capability is available to solve your difficult coupling problems. Please contact our representatives, or On Mark Couplings, Inc. 4440 York Blvd., Los Angeles 41, California...Clinton 4-2278.

On Mark Couplings REPRESENTATIVES: AIRSUPPLY AERO ENGINEERING DIVISION OF THE GARRETT [illegible] HILLS [illegible] MINEOLA, LONG ISLAND, N.Y. INDIANAPOLIS, IND. THE GARRETT CORPORATION OF CANADA LTD. MONTREAL

BEST WAY TO SEAL HOLES!
LEE PLUG
TAPERED PIN
PLUG GROOVED
Inserts by hand
REAMED DRILL HOLE
your castings
Simply place plug in reamed hole. Drive in tapered pin until ends are flush. Controlled expansion causes grooves to "bite" into casting, assures a bone dry seal that withstands pressures up to 40,000 psi. Now widely used on aircraft and missiles, and for pumps, servo valves, regulators, etc.
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LEE COMPANY
OLD SAYBROOK, CONN
WRITE TODAY FOR COMPLETE ENGINEERING DATA

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SECTION MANAGER

Advanced Systems Planning of Missiles

SALARY: $18,000 LEVEL

Section Manager needed for advanced systems planning of: tactical systems, defense systems, and space systems. Will advise and direct a group of engineers responsible for establishing the probable parameters of systems, as they affect, or are affected by, electronic considerations. Must have ability to plan weapon systems without established operational requirements, assessing prospective needs or trends, and analyzing suitability of requirements and concepts.

Will require minimum M.S. in Electronics or Physics with Doctors preferred, plus ten to fifteen years varied experience in electronics of weapon systems, including hardware development systems and advanced planning and proposal preparation. All applicants must have minimum six years at supervisory level.

Mail resume in confidence to Box #311, Space/Aeronautics

MAGNETIC TAPE—A 4-page illustrated bulletin 1619 describing Magnetic Tape for digital and analog recording is available from **Consolidated Electrodynamics Corp., Data Tape Division, Dept. S/A, 360 Sierra Madre Villa, Pasadena, Calif.** Information includes performance qualities of the new tape, production techniques, and specifications.

Write in No. 334 on Reader Service Card

FACILITIES—A six-page brochure that outlines engineering, research and development, production and testing facilities in the fields of propellant actuated devices, ground support equipment, and aircraft and missile sub-systems, among others, has been issued by **Horkey-Moore Associates, Dept. S/A, 24660 Crenshaw Blvd., Torrance, Calif.** Photographs include cover electronic, aerodynamic, pneumatic, hydraulic, and other activities.

Write in No. 335 on Reader Service Card

RESISTORS—A data sheet with dimensional drawings and complete technical data on their line of ¾ in. dia. miniature pre-set-wire wound variable resistors is available from **Chicago Telephone Supply Corp., Dept. S/A, Elkhart, Ind.**

Write in No. 336 on Reader Service Card

DECOMMUTATION—A new 8-page brochure "M-Series Ground Station for PAM/PDM Decommutation" is available from **Applied Science Corp. of Princeton, Dept. S/A, Box 4, Princeton, N.J.** The literature describes the various components of the ASCOP ground decommutation system and how they operate.

Write in No. 337 on Reader Service Card

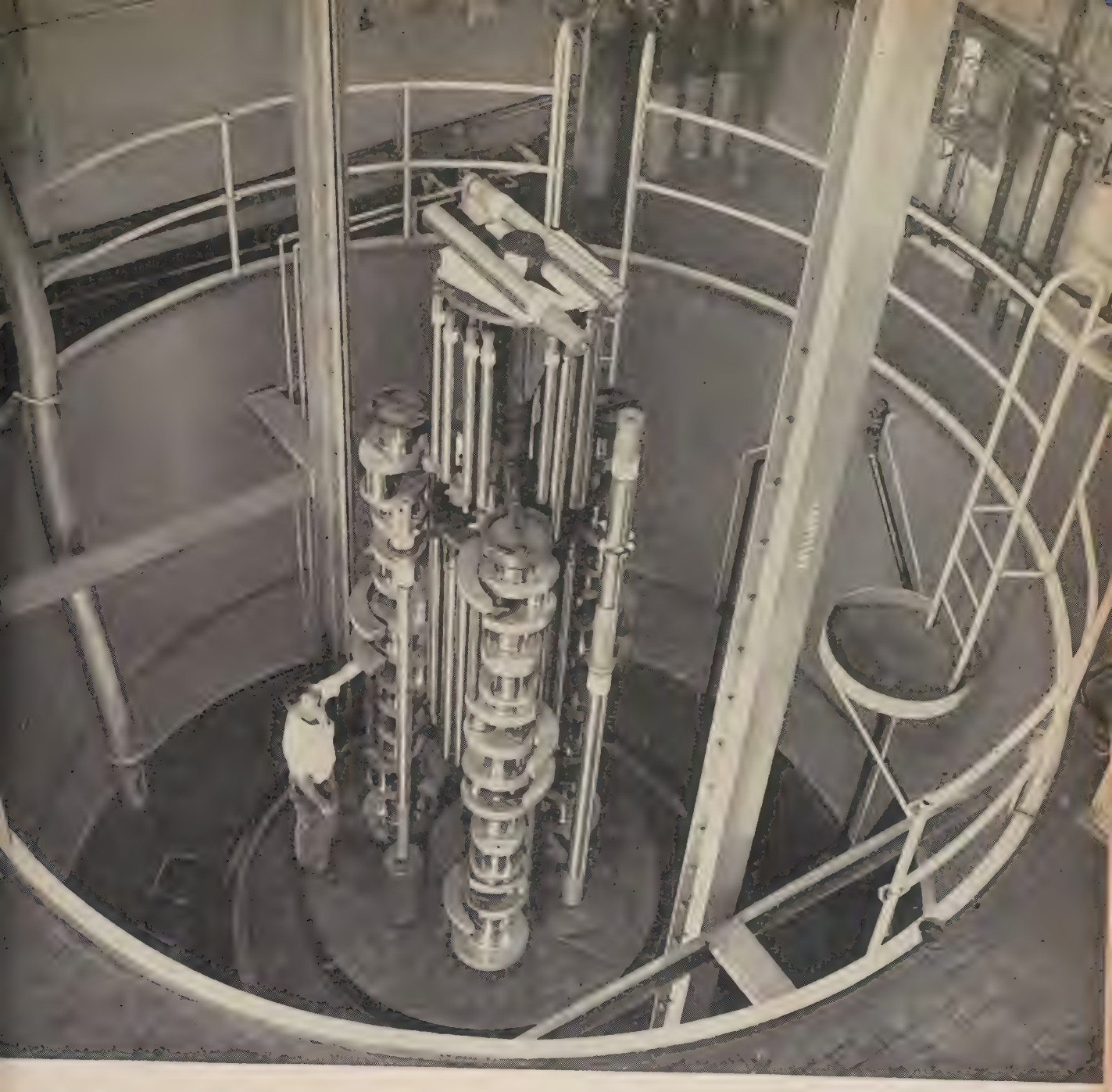
PULSE TRANSFORMERS — Catalog C202 24 pages in length, contains sections on definitions, ordering information, pulse transformer theory, application aids, testing and inspection tolerances, miniature and sub-miniature pulse transformers, pulse modulation and magnetron transformers, and is available on request from **Pulse Engineering Inc., Dept. S/A, 560 Robert Ave., Santa Clara, Calif.**

Write in No. 338 on Reader Service Card

ELECTRONIC COMPONENTS — Catalog 50, though designated formally as a "catalog" of military electronic components, is simultaneously an invaluable handbook on U.S. military specifications covering those components manufactured by **Ohmite Manufacturing Co., Dept. S/A, 36 Howard St., Skokie, Ill.** It includes products such as fixed power resistors,, adjustable power resistors, precision resistors, rheostats, tantalum capacitors and relays.

Write in No. 339 on Reader Service Card

more on page 3



WHO FORGES THE TOUGH ONES?...
and nitride-hardens them, too?

tional Forge does it—with a nitriding installation that is of the largest and most modern in existence. Now diesel akshafts, pump eccentrics, compressor pistons and rods, rs, marine couplings, and many other machinery parts are only *forged* at National, but *nitride-hardened* to add ngth and reduce wear. Vertical nitriding furnaces like the one illustrated will accommodate forgings up to 16 feet in length.

National Forge also has its own basic electric melting facilities and produces all the usual types of nitriding steels, including the recently developed 5% nickel, 2% aluminum grade. For further information, write for bulletin NF-60-01.

NF

NATIONAL FORGE COMPANY

IRVINE, WARREN COUNTY, PENNSYLVANIA

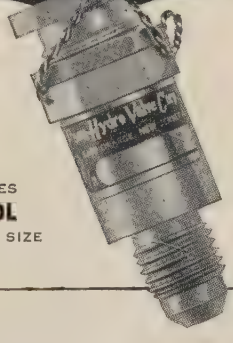
For more information on "the tough ones," and the machinery that makes them "best"—write for bulletin NFO

Write in No. 229 on Reader Service Card at start of Product Preview Section

Pneu-Hydro

SUBMINIATURE

PRESSURE RELIEF VALVES



SERIES 400L
ACTUAL SIZE

- Dependable Long Time Service
- Zero Leakage
- Chatter-Free Action
- Quick Positive Reseating
- Shipped From Stock

SPECIFICATIONS

Cracking Pressures: 200 to 4000 psi
Equivalent Orifice: .03" Dia.
Fluid Temperature: —100° to 250°F
Port Size: MS 33656-4
Weight: ½ ounce
Adaptable to Hydraulic Service

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Pneu-Hydro Valve Corp.
Engineers & Manufacturers of Hydraulic, Pneumatic & Cryogenic Components
50 Horse Hill Road
Cedar Knolls, New Jersey

Write in No. 230 on Reader Service Card

MICROPHONES—The NM 125 and NM 135, two high-intensity microphones designed for rugged environments have been described in Technical Brochure CI-NM 135, available from **B & K Instruments, Inc., Dept. S/A, 3044 W. 106th St., Cleveland 11, O.** Linear dynamic measurement range is 95 to 200 db, and both microphones use self-generating ceramic sensors with a —60 to +260-deg C operating range.

Write in No. 465 on Reader Service Card

SOLENOID VALVES—A 16-page catalog, the "Solenoid Valve Stock List and Selection Guide No. 506," has been offered by the **Automatic Switch Co., Dept. S/A, Florham Park, N.J.** Specifications, engineering information, construction figures and flow diagrams are included for all stocked ASCO valves.

Write in No. 340 on Reader Service Card

SWITCHES—A technical description of two new 13/16-in. diameter pull-push switches for electronic and electrical applications is contained in a data sheet for Catalog 71, available from **Chicago Telephone Supply Corp., Dept. S/A, Elkhart, Ind.** The switch offers greater simplicity of motion and easier handling than rotary or toggle switches.

Write in No. 341 on Reader Service Card

TESTING SYSTEMS—Automatic programable testing systems, which include systems for missile checkout, dynamic system testing, and quality control, have been described in Bulletin 1100 by **Consolidated Avionics Corp., Dept. S/A, 800 Shames Dr., Westbury, N.Y.** An automatic multiple circuit analyzer, universal test station, and a computer test set are the devices featured in the four-page bulletin.

Write in No. 464 on Reader Service Card

COUNTERS—A technical data sheet on the Series AD-1 bi-directional counters has been prepared by **Chicago Dynamic Industries, Inc., Dept. S/A, 1725 Diversey Blvd., Chicago 14, Ill.** The device counts hours, degrees, mils, and minutes among other values, does not count in multiples of ten, and has no interrupted gearing to complicate operation.

Write in No. 342 on Reader Service Card

VOLTAGE REGULATION — Effective voltage regulation in three-phase circuits by means of single-phase ac line-voltage regulators is the subject of Application Bulletin AC610, available from **Sorensen & Co., Dept. S/A, South Norwalk, Conn.** The bulletin covers the use of three single-phase regulators.

Write in No. 343 on Reader Service Card

CAPABILITIES—A 16-page brochur that outlines its general capabilitie has been issued by **Whittaker Con trols Div., Telecomputing Corp Dept. S/A, 915 N. Citrus Ave., Lo Angeles, Calif.** The company's inter ests extend to pneumatics, hydraulics fuel systems, and electric compon ents, as they apply to a variety c control and actuator applications i the missile and other fields.

Write in No. 344 on Reader Service Ca

TRANSFER PUMP—A catalog shee describing a close-coupled petro chemical and cryogenic transfer pum for high-flow continuous or intermi tent duty for any fluid has been pre pared by **Turbocraft, Inc., Dept. S/A 492 E. Union St., Pasadena, Cali** The Series 3000 pump operates a very low values of net positive suc tion head without adversely affectin performance.

Write in No. 345 on Reader Service Ca

ELECTRIC MOTORS — High-precisio hysteresis synchronous electric moto for missile and aircraft instrumenta tion, computer drum drives, and tap transports, among other component are discussed in a four-page bulleti available from **Hysyn Electromotiv Dept. S/A, 915 N. Citrus Ave., L Angeles 38, Calif.** Performanc characteristics, dimensions and co struction are considered, along wi design features and characteristics.

Write in No. 346 on Reader Service C

FACILITIES—"For Proving and I proving Product Performance" is eight-page brochure outlining t aircraft and missile electrical, electr mechanical and electronic compone testing capabilities of **Astrolab Te ing Corp., Dept. S/A, 11615 McBe Dr., El Monte, Calif.** Laborato equipment, testing procedures a processes are illustrated.

Write in No. 347 on Reader Service Ca

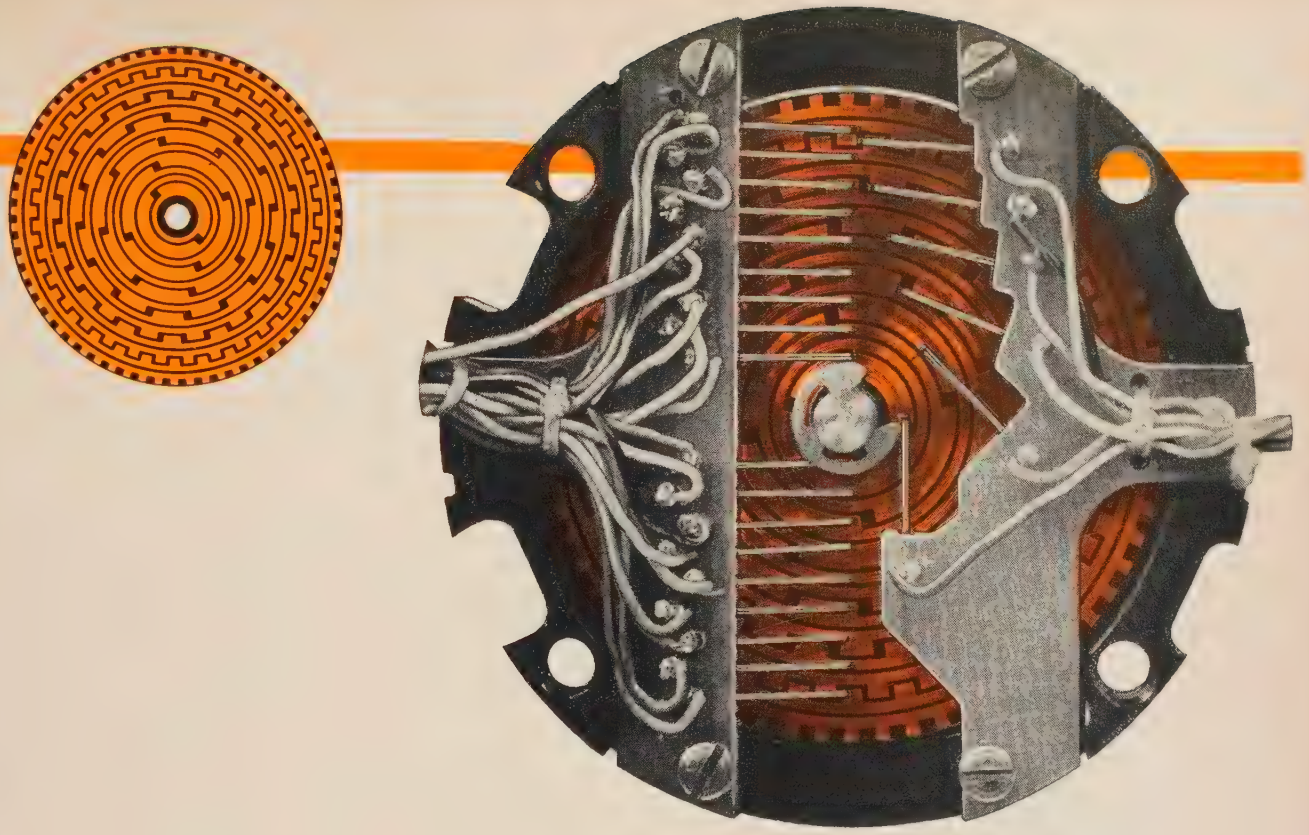
REACTANCE SLIDE RULE — Co structed of durable plastic for lon lasting service, the Reactance Com puter Slide Rule is 9½ in. long a is available to electronic enginee at the cost of one dollar each dire from **JFD Electronics Corp., Dep S/A, 6101 Sixteenth Ave., Brookl 4, N. Y.**

Write in No. 348 on Reader Service Ca

INSTRUMENTATION—Catalog G- containing 48 pages describes t scientific and test instruments man factured by **Minneapolis-Honeyw Regulator Co., Dept. S/A, Wayne Windrim Ave., Philadelphia, Pa.** Sp cifications, illustrations, and referen material is included for each fam of instruments.

Write in No. 349 on Reader Service C

more on page 3



Norden converters eliminate external electronics, simplify circuitry by non-ambiguous, self-selecting brush design

Unique Norden self-selecting V-scan pattern translates analog input into digital electrical representation by means of self-contained, non-ambiguous, dual brush-selection logic. This Norden design

- offers the *only* shaft position encoders to qualify under MIL-E-5422D and MIL-E-5272A.
- simplifies total system design and reduces cost.
- has provision for automatic error-monitoring.
- has precision brushes, fewer components and unambiguous output assuring highest reliability.
- saves space . . . ideal for subminiature techniques.
- permits direct parallel readout accurately following the shaft position even at highest shaft speeds.
- has longer life because no load current-carrying brush ever commutates; insulation of only 19% of disc area minimizes brush wear and insulation dust.

MODEL NO.	TOTAL COUNT	REVOLUTIONS PER COUNT	(1 PART IN) ACCURACY
ADC-ST7-BNRY	2^7	1	128
ADC-13-BNRY	2^{13}	64	8192
ADC-19-BNRY	2^{19}	4,096	524,288
ADC-ST8P-BNRY	2^8 (with parity)	1	256
ADC-ST9-BNRY	2^9	1	512
ADC-ST10-BNRY	2^{10}	1	1024

These Norden self-selecting V-Brush encoders fit a wide variety of applications. For complete specifications and drawings, call Milford, Connecticut, TRinity 4-6721. If your requirements demand special variations, Norden engineers will work out a custom design.

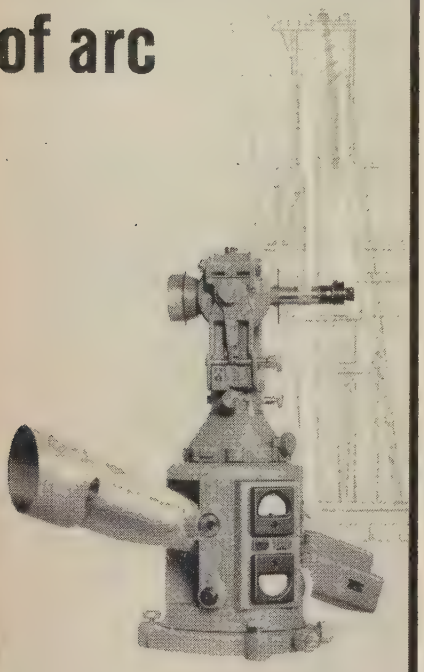
NORDEN

DIVISION OF UNITED AIRCRAFT CORPORATION

Milford Department, Wiley Street, Milford, Connecticut

Write in No. 231 on Reader Service Card at start of Product Preview Section

Azimuth alignment to one second of arc



J. W. Fecker's new Azimuth Alignment Portable Theodolites give sensitivity and reproducibility to one second of arc!

Model 100's simplified optical autocollimating system provides a single light source with no need for light balance or regulation of power to light source. Phase rather than amplitude measuring systems make the unit insensitive to electrical noise and light variations.

Miniaturized electronic controls are available as an integral part of the instrument or may be remotely located.

Want to know more about Model 100? Or about equipment designed specifically to meet your needs? Write.

j. w. fecker

Division of American Optical Co.

6592 Hamilton Ave., Pittsburgh 6, Pa.

Write in No. 232 on Reader Service Card

DATA PREVIEW

HYDRAULIC CONTROLS—HC 2.20 is a four-page folder on a few of the hydraulic controls designed for aircraft and missile use by **Whittaker Controls Div., Telecomputing Corp., Dept. S/A, 915 N. Citrus Ave., Los Angeles 38, Calif.** Included is information on selector, poppet and shut-off relief valves, and hydraulic system components.

Write in No. 350 on Reader Service Card

SWITCHING TRANSISTORS—A 24-page booklet lists maximum ratings and electrical characteristics for all PNP and NPN medium and high speed types in the switching transistor line manufactured by **Sylvania Electric Products Inc., Dept. S/A, 1100 Main St., Buffalo 9, N.Y.** The booklet is entitled "Medium and High Speed Switching Transistors."

Write in No. 351 on Reader Service Card

CONNECTORS—The BT Series of insert contact arrangements are illustrated in a catalog insert on the Bantam line of miniature electronic connectors made by **H. H. Buggie Div., Burndy Corp., Dept. S/A, Box 817, Toledo 1, O.** The vibration- and moisture-resistant connectors are designed for interchangeability with other miniature connector styles.

Write in No. 352 on Reader Service Card

FACILITIES—A 24-page report on the engineering and production facilities of its four plants and research laboratory has been made available by **Moog Servocontrols, Inc., Dept. S/A, East Aurora, N.Y.** The report covers the equipment useful in the development and production of precision electro-hydraulic servo components for aircraft, missile and industrial systems.

Write in No. 353 on Reader Service Card

FUEL PUMP—A turbine-driven fuel pump, the Model 102, suitable for use at altitudes from sea level to 48,000 ft, has been described in a catalog sheet by **Santa Barbara Div., Curtiss-Wright Corp., Dept. S/A, 6767 Hollister Ave., Goleta, Calif.** The pump can be run without lubrication for extended periods and is rated for 10,000 lbs/min fuel flow.

Write in No. 354 on Reader Service Card

TACH-GENERATOR—A data sheet on a one-in limited angle tach-generator has been issued by **Gloster Aircraft Co., Ltd., Dept. S/A, Gloucester, England.** The device is designed to operate over a limited movement of ±15 deg, has a large output proportional to shaft speed, and is suitable for use as a feedback generator in servo-systems subject to rugged environments.

Write in No. 355 on Reader Service Card

more on page 332

Ideal Aerosmith is the leader in the designing and building of Precision valves for critical control or metering of liquids or gases.

LOOK FOR THESE FEATURES:

- Micrometer type vernier scales available on most sizes and models for consistent repeatability.
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- Available in Bronze or 18-8 stainless steel.
- Available in ⅛" to ½" pipe size.
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Some choice distributorships are still available

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GRaystone 4-3600 in San Francisco
HOllywood 5-1131 in Los Angeles
MAin 3-6688 in Seattle
or Teletype LA 1840 in Los Angeles

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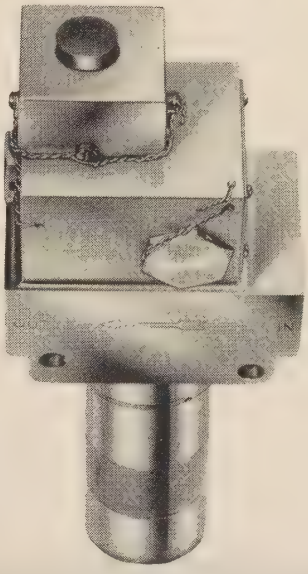
NEW NEW FROM PUROLATOR:

A FILTER THAT TELLS YOU WHEN IT NEEDS CLEANING

The indicator in the top of this new Purolator filter pops up automatically the moment the element is too clogged to filter accurately. When the element has been cleaned, you simply depress the button until it resets automatically. It stays down, hidden, until the next cleaning is due. That's all there is to it.

WHERE CAN YOU USE IT?

In any fluid system (up to 275°F, 5000 psi) where differential pressure can be used for measurement. The mechanical indicator filter can be made for practically all sizes and operating conditions. It can be designed with or without relief valves and by-pass arrangements.



High filtrate viscosity caused by low temperature won't trigger the indicator because the piston is locked in place below 30°F.

HOW FINE DOES IT FILTER?

Anywhere from 5 to 50 microns, depending on the filtering medium used. Units now in production meet indicator requirements for proposed MIL SPEC: MIL-F-8815.

HOW BIG IS IT—HOW MUCH DOES IT WEIGH?

Check through the chart of standard specifications below. If you want more information, fill in the coupon and mail it to Purolator Products, Inc., Department AW50, Rahway, New Jersey.

STANDARD SPECIFICATIONS

	G-416-1 ASSEMBLY NO. 60878	ASSEMBLY NO. 6652965	ASSEMBLY NO. 6652922
MATERIAL	(Capacity — 5 GPM)	(Capacity — 12 GPM)	(Capacity — 23 GPM)
Head	Aluminum	Aluminum	Aluminum
Case	Aluminum	Aluminum	Aluminum
Element	Stainless Steel Wire Cloth	Stainless Steel Wire Cloth	Stainless Steel Wire Cloth
DIMENSIONS			
Overall	$8\frac{5}{64}$" long x 3" (btw. conn.)	$9\frac{7}{16}$" long x 4" (btw. conn.)	$12\frac{27}{32}$" long x $4\frac{1}{2}$" (btw. conn.)
Element	$1\frac{1}{16}$" O.D. x $3\frac{15}{16}$" long	$1\frac{3}{4}$" O.D. x $4\frac{7}{16}$" long	2" O.D. x $7\frac{3}{8}$" long
Connections	$\frac{7}{8}$-14 UNF-3B (AND 10050-10)	$1\frac{1}{16}$-12 UN-3B (AND 10050-12)	$1\frac{5}{16}$-12 UN-3B (AND 10050-16)
Indicator Actuation	80 PSI at temperatures over 30° ± 20°F	70 PSI at temperatures over 30° ± 20°F	80 PSI at temperatures over 30° ± 20°F
Maximum Operating Pressure	3000 PSI	5000 PSI	4500 PSI
Maximum Operating Temperature	225°F	275°F	275°F
Weight of Complete Unit	1.8 lbs.	4 lbs.	6 lbs.
Degree of Filtration	25 Microns Absolute	25 Microns Absolute	25 Microns Absolute
Element Withstands	3750 PSI	3000 PSI	500 PSI
Relief Valve Setting	None	None	225 PSI

Filtration For Every Known Fluid

PUROLATOR

PRODUCTS, INC.

RAHWAY, NEW JERSEY AND TORONTO, ONTARIO, CANADA

Purolator Products, Inc.
Dept. SA-50, Rahway, New Jersey

____Please send further information on Purolator's exclusive Mechanical Indicator Filter.
____I have enclosed a drawing of my filtration problem. What do you recommend?

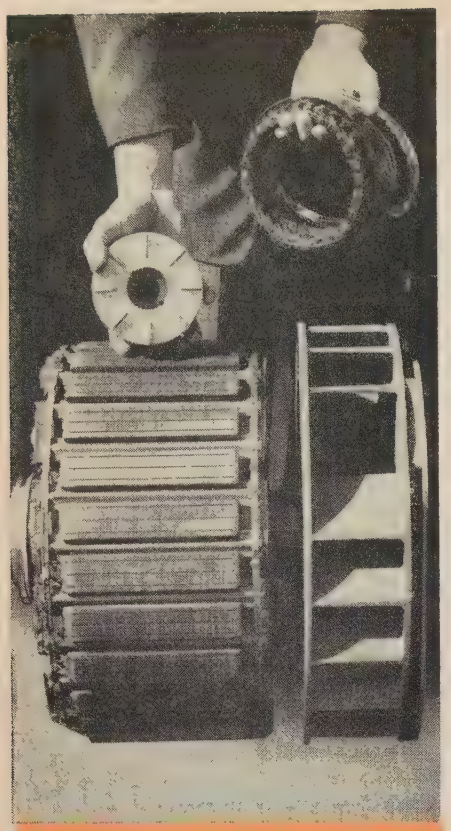
Name_____

Company_____

Address_____

City_____ Zone_____ State_____

Write in No. 235 on Reader Service Card at start of Product Preview Section



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100 kilowatts or ½ kilowatt... whatever your job requirement American MARC generators are your best power buy. Three types of generators are available! 1. Permanent magnet generators from ½ to 8 kw designed for continuous operation under adverse conditions. 2. Static-excited generators from 5 to 100 kw...noteworthy for precise voltage control (to ¼ of 1%), improved transient response and exceptional motor starting characteristics. 3. Brushless generators from 10 kw to 100 kw...economical, easy to maintain.

Write, wire or 'phone for complete information.

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phone: ORegon 8-7174

1601 West Florence Avenue, Inglewood, Calif.

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TRANSCEIVERS – A 4-page booklet 321A describing the features and performance of a new automatic acceptance tester for TACAN transceivers has been issued by the **Stromberg-Carlson Electronics Div., Dept. S/A, Rochester 3, N.Y.** The tester automatically sequences through the entire 126 TACAN channels without operator supervision, and prints out the results on tape, numbered according to the channel tested.

Write in No. 356 on Reader Service Card

STAINLESS STEEL—A data chart, Sec. A, No. 4, provides a comparison of properties for 18 grades of stainless steel has been prepared by **Peter A. Frasse & Co., Inc., Dept. S/A, 17 Grand St., New York 13, N. Y.** It includes recently developed precipitation harding grades, 17-4 and 17-7.

Write in No. 357 on Reader Service Card

FREQUENCY CONVERTER—Information on the W-1477 frequency converter, a static 400-cycle power supply that changes 60-cycle power to aircraft or missile 115/200, three-phase, 400-cycle power with a 750 va load capacity, has been released by the **Electrosolids Corp., Dept. S/A, 13745 Saticoy St., Panorama City, Calif.** The portable, ground-support unit has an expected operating life of over 25,000 hrs.

Write in No. 358 on Reader Service Card

GATE VALVE—Special templates for actual-size tracing of standard gate valves are included in a four-page brochure describing the gate valve line of **Whittaker Controls Div., Telecomputing Corp., Dept. S/A, 915 N. Citrus, Ave., Los Angeles, Calif.** The brochure will assist fluid system engineers and draftsmen in preparing actual scale checks of component clearances and location.

Write in No. 359 on Reader Service Card

GROUND SUPPORT—A four-page brochure on building-block types of ground support equipment systems for aircraft and missiles has been released by **Lear, Inc., Dept. S/A, P.O. Box 688, Grand Rapids 2, Mich.** Magnetic particle clutchs, servos, control components, and power units are among the building blocks, which are available as separate components or in system groupings.

Write in No. 360 on Reader Service Card

BUS DUCT – "High Frequency Bus Duct" is a 12-page bulletin describing the new bus duct of **Westinghouse Electric Corp., Dept. S/A, P. O. Box 2099, Pittsburgh 30, Pa.** The booklet includes a curve of voltage drop at 400 cps plotted against load.

Write in No. 361 on Reader Service Card

FACILITIES—A facilities and capabilities brochure outlining their engineering services and products for automatic measurements and control of processes is offered by **American Bosch Arma Corp., Chicago Div., Dept. S/A, Oak Lawn, Ill.** Various types of ground support equipment and production test equipment are depicted.

Write in No. 362 on Reader Service Card

EXPLOSIVE ACTUATION—The operating principles of the Exploding Bridgewire System, which is designed for initiating missile and space vehicle ordance functions, have been presented in a six-page brochure available from **Librascope, Inc., Dept. S/A, 670 Arques Ave., Sunnyvale,** Calif. Rocket motor initiation, missile stage separation, missile destruction, and warhead initiation are the functions discussed.

Write in No. 363 on Reader Service Card

CONTACT RELAYS—Mercury-wetted contact relays with an operating life of over eight billion operations are described in Catalog 201, available from **C. P. Clare & Co., Dept. S/A, 3101 Pratt Blvd., Chicago 45, Ill.** Relay types include those for single- and multi-element operation, and they are biased with permanent magnets or are adjustable to provide single-side-stable, bi-stable or chopper characteristics.

Write in No. 364 on Reader Service Card

OXIDATION PUMPS—The effectiveness of sealless "canned" pumps for leakproof pumping of fuels and oxidizers for missiles and jet engines has been discussed in Technical Bulletin #1, available from **Chempump Div., Fostoria Corp., Dept. S/A, P.O. Box 35-20, Huntingdon Valley, Pa.** The four-page bulletin offers information on handling problems.

Write in No. 365 on Reader Service Card

WELDING—The Heliarc line of manual welding equipment is described in catalog F-8982E prepared by **Linde Co., Dept. S/A, 30 E. 42 St., New York 17, N. Y.** Each unit is illustrated and accessories are covered

Write in No. 366 on Reader Service Card

DRIVE SHAFTS—Details of a line of flexible drive shafts designed to provide power transmission at constant velocity ratio are offered in the four-page Publication 19U-6-812D, available from **Utica Div., Bendix Aviation Corp., Dept. S/A, 211 Seward Ave., Utica, N.Y.** The Flex Shafts are useful in many aircraft applications.

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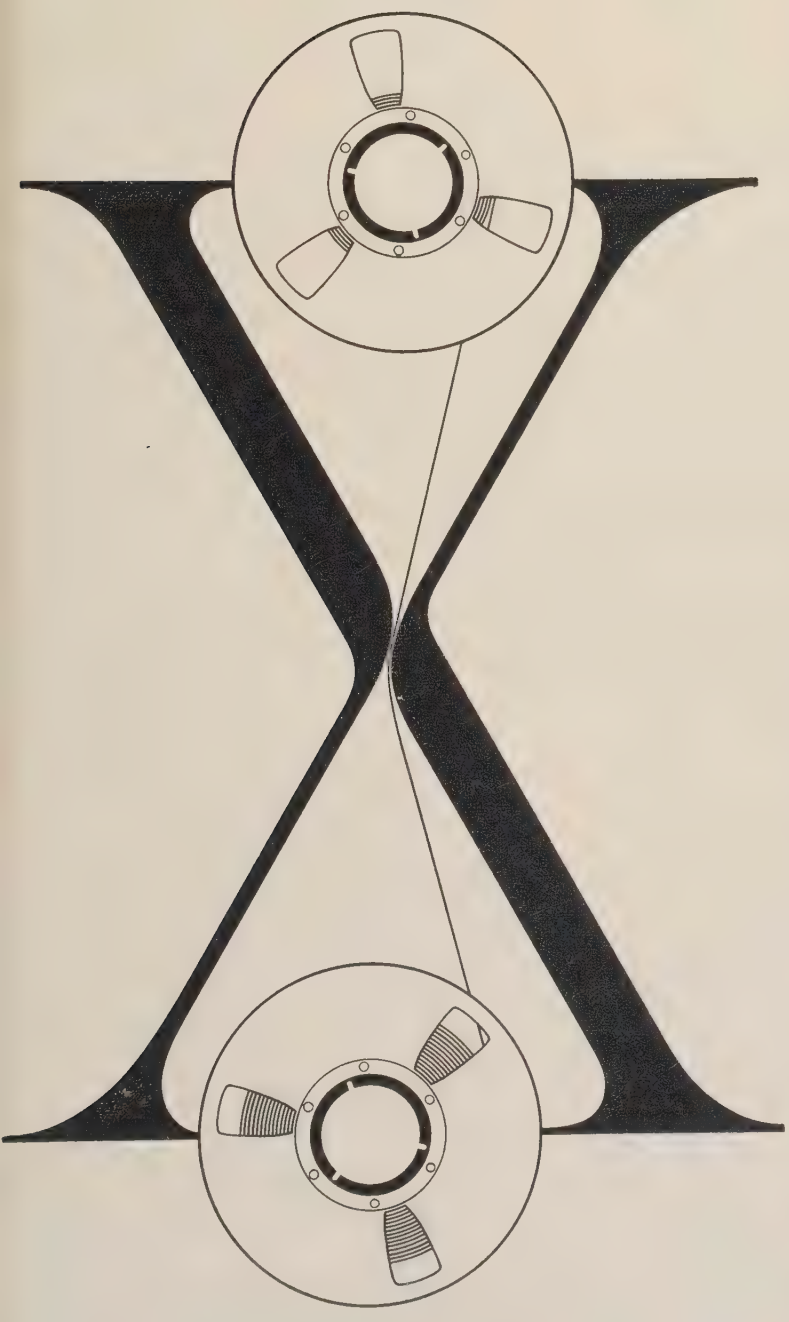
more on page 336

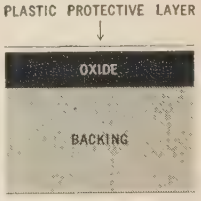
NO DOUBT ABOUT IT—

"SCOTCH" BRAND Sandwich Tapes wear 10 times as long without errors



IN THAT NARROW LITTLE LIFELINE OF DATA known as magnetic tape, a miss is magnified into a mile. A missed bit, or one picked up by error is confusing, frustrating and time-consuming. If you're in doubt about the kind of performance you're getting, perhaps "SCOTCH" BRAND Sandwich Tapes can solve some of your tape and equipment problems.

The exclusive construction of the Sandwich Tapes combats the causes of error because it eliminates the source—oxide rub-off and head build-up. Tests prove it wears a minimum of 10 times as long as ordinary tapes before it errs. As a by-product, you can rely on it to drastically reduce maintenance and replacement costs on equipment.



The Sandwich is constructed as shown in the diagram at the right. The famous "SCOTCH" BRAND high potency oxide coating is sandwiched between a tough polyester base and a 50 micro-inch layer of plastic. Since the oxide is never in contact with the head, tape movement is smooth and low in friction—easy on both tape and equipment. Oxide can't rub off and distort valuable data.

Yet, the real meat of this remarkable Sandwich is the "SCOTCH" BRAND high potency oxide coating. Even under the protective plastic, the oxide's potency is quite sufficient to pick up 500 pulses per inch—and give desirable high-frequency response in many AM, FM and PDM applications. Sandwich Tape is but one of the developments to come out of 3M research—the same research responsible for "SCOTCH" BRAND Video Tape—the first video tape in commercial use.

Whatever your application—you'll find the right tape for reliable, error-free performance in the "SCOTCH" BRAND line-up. Check them all. *High Resolution Tapes 158 and 159* pack more bits per inch, offer either standard or extra-play time. *New Heavy Duty Tapes 198 and 199* offer good resolution and exceptional life even in poor environments. *High Output Tape 128* gives top output in low frequencies, even in temperature extremes. And *Standard Tapes 108 and 109* remain the standard of instrumentation.

Your 3M Representative is close at hand in all major cities—a convenient source of supply and information. For details, consult him or write Magnetic Products Division, 3M Co., St. Paul 6, Minnesota.

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CAREER OPPORTUNITIES AT ATLANTIC MISSILE RANGE AND FORT HUACHUCA

Service to scientific exploration has been performed by the Guided Missiles Range Division of Pan American World Airways since 1953.

Pan American has prime responsibility for the engineering, operation and maintenance of the Air Force Missile Test Center's 5,000 mile Atlantic Missile Range beginning at Cape Canaveral.

Now, having been awarded a prime contract by the Army Signal Corps, Pan Am has the new responsibility for engineering and operating an Electronic Environmental Test Facility near Fort Huachuca, Arizona. Fort Huachuca will be the brain center of the Test Facility, where information gathered in the field will be analyzed in the Army's automatic data processing facilities, among the most modern and complete in the world.

Additionally, Pan Am will engineer, install, operate and maintain facilities for a test range for Army drone aircraft, with drone flights to be monitored by radars, telemetry, and optical equipments.

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- Radar Operators
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To investigate career opportunities with Pan Am at the Atlantic Missile Range, contact J. B. Appledorn, Dept. T-15, Guided Missiles Range Division, Patrick AFB, Florida; or at Fort Huachuca, contact C. A. Hoskins, Dept. T-15, 1537 East Broadway, Tucson, Arizona.

PAN AM

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Check Employment Inquiry Form on Page 211

Photo courtesy Convair Aircraft Division, General Dynamics Corp.

for optical clarity

Convair 880's* use L·O·F Aviation Glass

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For use in control systems and testing applications where long term stability, accuracy and dependability under extreme environmental conditions are a must.

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DATA PREVIEW

TURBOJET ENGINE—Progress report on the J85 turbojet engine operates and tests are summarized in bulletin GED-4002 issued by **General Electric Co., Dept. S/A, Schenectady 5, N. Y.** It describes engine operating and field maintenance experience, overall powerplant test programs, and specifications for dry and re-heat configurations.

Write in No. 368 on Reader Service Card

AERIAL CAMERA — Rapid scanning principles to obtain successive horizon-to-horizon photographs covering 180 deg across an aircraft's line of flight are used in the Model 501 panoramic camera described in an eight-page brochure by **Perkin-Elmer Corp., Dept. S/A, Norwalk, Conn.** The lightweight camera features automatic sequencing and a capacity for sufficient film to cover a complete mission.

Write in No. 369 on Reader Service Card

CRYOGENICS—The physical property equivalents of cryogenic fluids most useful to engineers in the chemical and missile industries have been compiled in tabular form and presented in a folding pocket card available from **Linde Co., Dept. S/A, 30 E. 42nd St., New York 17, N.Y.** Boiling and melting points, critical temperatures and pressures, thermal equivalents, and conversion factors are among the data included.

Write in No. 370 on Reader Service Card

RATE GYROS — A comprehensive treatment of subminiature rate gyroscopes has been published as a 62-page technical manual by **Sanders Associates, Inc., Dept. S/A, 95 Canal St., Nashua, N.H.** Basic principles of operation, operating characteristics, standard available types, and general application information for fire control systems, missile homing and other uses are among the topics covered.

Write in No. 371 on Reader Service Card

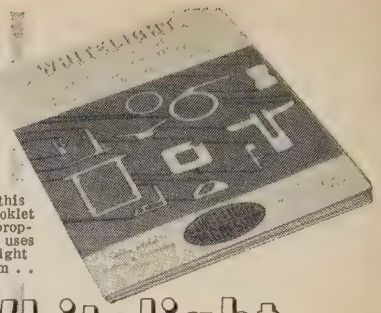
CLUTCHES & BRAKES — Electromechanical clutches and brakes suitable for aircraft and missile use are among the devices described in a four-page products folder issued by **Carmody Corp., Dept S/A, 2360 Wehrle Dr., Buffalo 21, N.Y.** Information on aircraft flight trainers is also included.

Write in No. 372 on Reader Service Card

DIFFERENTIAL AMPLIFIER—A six-page brochure on the Fitgo differential amplifier and accessories has been issued by **Beckman Systems Div., Dept. S/A, 325 N. Muller Ave., Anaheim, Calif.** Bulletin 3015-B includes complete specification coverage for the solid state amplifiers.

Write in No. 373 on Reader Service Card

more on page 338



Send for this helpful booklet covering properties and uses of Whitelight Magnesium . .

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your comprehensive independent mill source of magnesium alloy . .

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AZ81
ZK60
ZK30
M-1
ZK-20
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SOLID SHAPES—.022" min. to 6½" circle
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HOLLOW SHAPES—¼" to 6½" circle
PLATE and SHEET—.092" to 3" thick (36" and less)

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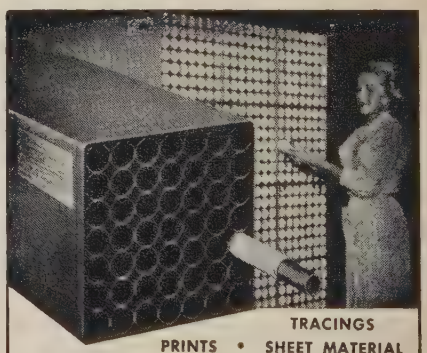

TRACINGS
PRINTS • SHEET MATERIAL

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Depth	11¼"	22¼"	30½"	36½"	42¼"
49 Tube 1¾" I.D. MODEL	49AB $7.50	49CD $9.50	4930 $12.80	4936 $13.80	4942 $14.80
25 Tube 2¼" I.D.	25AB $7.00	25CD $9.00	2530 $11.80	2536 $12.80	2542 $13.80

Shipping Weight

Model 49	8 lbs.	12 lbs.	15 lbs.	18 lbs.	20 lbs.
Model 25	6 lbs.	10 lbs.	13 lbs.	15 lbs.	17 lbs.

ENAMELED DARK GREEN OR MED. GRAY - State Color

JR 36
Designed to Mount Under Board—Mounting Brackets Furnished. Gray Only.
Sold in Sets Only—2 JR36 Per Set
9.50 SET of TWO
8 lbs. Ship. Wt.

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ROLL & FILE SYSTEMS, INC. P. O. BOX 3863 B DETROIT 5, MICH

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Safety Valve FOR AN ASTRONAUT

If America's first man-carrying rocket runs into trouble, a unique Donner device will play a vital role in bringing the Astronaut safely back to earth.

Known as a "maximum altitude sensor," the all solid-state system is essentially a fixed purpose miniature analog computer housed in a magnesium case only five inches long. Installed in the capsule, it goes into action if it is necessary to abort the rocket flight before the Astronaut's escape tower is jettisoned.

What it Does

The Donner device, which was developed for McDonnell Aviation with the approval of NASA, provides programmed time delay that operates rescue devices at maximum altitude.

Under abort conditions, the maximum altitude sensor provides output information which will:

1. Energize devices for firing the explosive bolts holding the escape tower onto the top of the capsule. This allows the escape tower to separate.

2. Energize the system which causes the escape tower jettison rocket to fire. With the tower separated, barostats are armed to open parachutes and furnish the Astronaut's capsule a safe descent.

Specialists in Analog & Digital Dynamics

Donner's maximum altitude sensor is another product from a firm specializing in the manufacture of accurate fixed and general purpose analog and digital systems designed to analyze, measure, and control inputs interlocking time, acceleration, jerk, velocity, and other dynamic inputs.

If you would like more information concerning our capabilities, contact your nearby Donner engineering representative or write us today.

DONNER SCIENTIFIC COMPANY
CONCORD, CALIFORNIA
Phone MUlberry 2-6161

Write in No. 242 on Reader Service Card at start of Product Preview Section

BELLOWS—Molded Fluoroflex-T Flex joints and bellows made from Teflon for non-standard, low- and high-temperature and corrosive applications have been described in a four-page bulletin issued by **Resistoflex Corp., Dept. S/A, Roseland, N.J.** Bellows applications include use as flexible pickup tubes inside tanks carrying lubricating oil and other fluids, and as connections between fuel cells in aircraft or missiles.

Write in No. 374 on Reader Service Card

CAPABILITIES—An illustrated brochure on its capabilities in the development and manufacture of aircraft and missile components has been issued by **Poly Industries, Dept. S/A, 12177 Montague St., Pacoima, Calif.** Company products include fuel mixing valves, turbine buckets, honeycomb flooring, missile launchers, rocket motor control valves, blowers, and helicopter rotor blades, among others.

Write in No. 375 on Reader Service Card

INSTANT RE-STARTS AFTER FLAMEOUTS . . . WITH BENDIX FUEL NOZZLES

When flameouts occur, instant re-starts are a "must". That's a big reason why Bendix® Fuel Nozzles are being chosen for more and more jet engines every day. These nozzles solve in-flight re-start fuel problems completely—provide sure cold starting on the ground.

Missile and helicopter power plant manufacturers, too, favor Bendix Fuel Nozzles for faster, surer starts.

Explanation: these nozzles feature advanced design and precision construction that mean more dependable performance and greater economy all along the line.

Write for complete information.

Bendix-Elmira
Eclipse-Machine Division
Elmira, N. Y.

Bendix AVIATION CORPORATION

Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.

Write in No. 243 on Reader Service Card at start of Product Preview Section

PARTS PROCESSES—Stamping, upset forging, rotoforming, and other finishing processes are discussed in bulletin 900-Pf prepared by **Commercial Shearing & Stamping Co., Dept. S/A, 1775 Logan Ave., Youngstown 1, Ohio.** It describes metal components for construction and fabricated products, machinery and equipment, transportation equipment, and missiles and rockets.

Write in No. 376 on Reader Service Card

GENERATORS—Engineering specifications and application descriptions of electrical components for missile and aircraft ground equipment are contained in bulletin GEA-6973 issued by **General Electric Co., Dept. S/A, Schenectady 5, N. Y.** It covers such equipment as high speed aircraft-type alternators, regulators and exciters; semi-industrial alternators, regulators and exciters; ac to ac and ac to dc motor-generator sets and static speed and voltage regulated motor alternator sets.

Write in No. 377 on Reader Service Card

HEATERS—A four-page catalog describing its work in molded-to-shape electrical heaters with integral insulation has been released by **Electro-Flex Corp., Dept. S/A, 443 E. Alondra Blvd., Gardena, Calif.** The devices can be used in missile, aircraft, electronic and industrial applications.

Write in No. 378 on Reader Service Card

GROUND SUPPORT — An illustrated brochure containing photographs and descriptions of ground support equipment for the Redstone, Jupiter, and other missiles has been issued by **Designers for Industry, Inc., Dept. S/A, 4241 Fulton Parkway, Cleveland 9, Ohio.** In addition, the publication contains various frequency standards and programers with illustrations and specifications.

Write in No. 379 on Reader Service Card

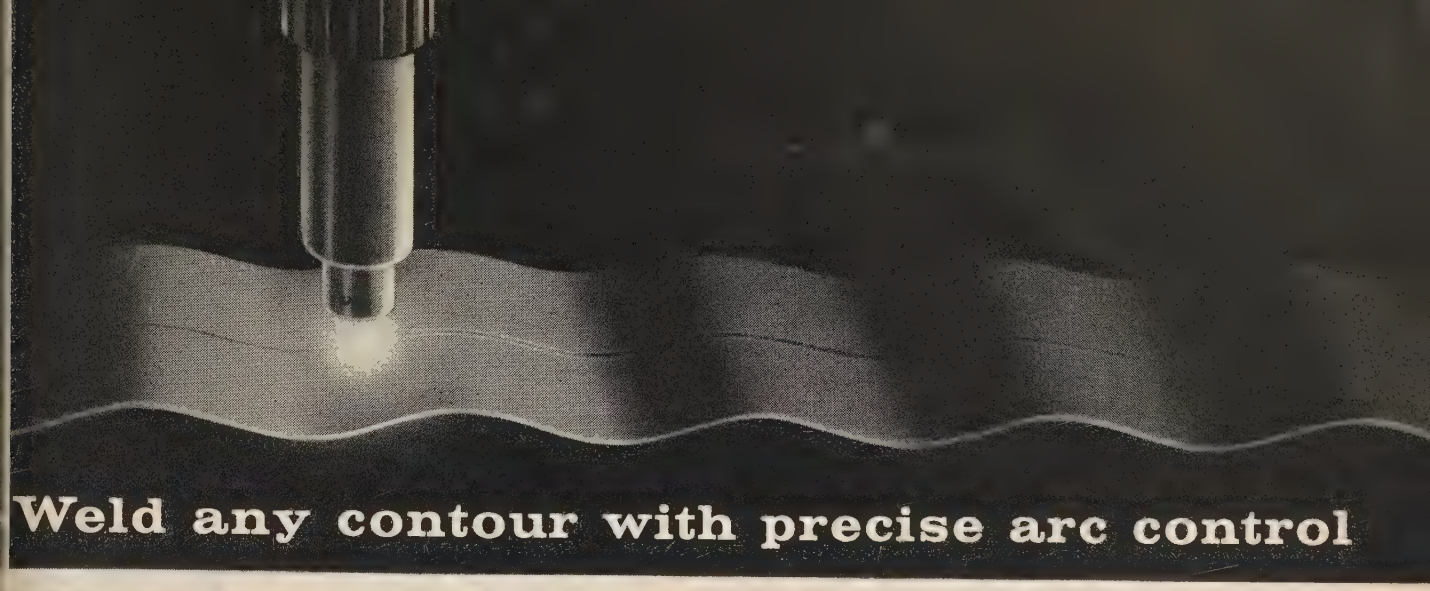
TESTING FACILITIES — A brochure describing the testing and development facilities has been prepared by **Avro Aircraft, Ltd., Dept. S/A, Box 4004, Terminal A, Toronto, Ont., Canada.** Laboratory services are discussed. Bulletin No. 2 is a technical folder on environmental testing.

Write in No. 380 on Reader Service Card

ALLOYS—A bulletin on tubing and pipe, describing applications and qualities, has been issued by **The Carpenter Steel Co., Alloy Tube Div., Dept. S/A, Union, N. J.** It contains tables of chemical analysis and physical and mechanical properties, size ranges and tolerances.

Write in No. 381 on Reader Service Card

more on page 341



Weld any contour with precise arc control

...in hard-to-reach places

NEW Airco Automatic Heliweld Head

Get top quality welds every time – even on irregular contours or in restricted areas – with Airco's new *Automatic Heliweld Head*. With this new design, you're sure of precise arc length control over *all* surfaces . . . accurate, automatic welding in *all* positions . . . vibration- and wobble-free operation *all* the time. What's more, you can set it to weld aluminum (on AC) or ferrous materials (on DC)—at the flick of a switch. Sensitivity is maintained with argon or helium.

The new Airco Automatic Heliweld Head is right at home on the toughest jobs. Internal circumferential seams, for example, are handled easily with the 3″ or 12″ offset arms. Tilting mechanism provides accurate, controlled welding through 360°.

Take your choice of two models. Model HMH-E takes electrodes up to 24″. Model HMH-D takes electrodes to 7″, and is provided with rotatable offset arms of 3″ and 12″, greatly increasing your ability to weld hard-to-reach spots.

Get full details on the new Airco Automatic Heliweld Head now. Call your nearest Air Reduction Office.

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Write in No. 244 on Reader Service Card at start of Product Preview Section

Ayres' Aerial Machine, designed by Dr. W. O. Ayres in 1885, was intended to get off the ground through compressed air generated by foot power. In this illustration of the machine, Brussel-Smith, noted graphic artist, has used his unique wood engraving technique to depict for this advertisement another of man's efforts to find the power necessary for sustained flight.

IMAGINATION IN SPACE

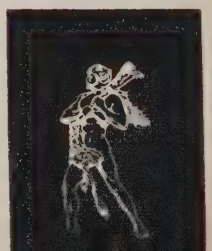
Since Creation, man has looked out on space. At first, unknowing and incurious; then with the beginnings of understanding; now free and able to explore. Yet to move in space calls for wholly new concepts of energy.

This, then, is the working philosophy of Hercules in chemical propulsion: To design and manufacture highly concentrated packages of energy as propellants and rocket motors; each compatible, controllable, predictable; and each perfected for its specific mission.

HERCULES' BACKGROUND: A half-century of creative imagination in the evolution of propellants, from shotgun powder to the manufacture of every one of the millions of U. S. rockets fired during World War II, and now to space propulsion. Hercules facilities today encompass research, design, engineering, and staff organization for the production of the most advanced propellants. Illustrated brochure available on request.

HERCULES POWDER COMPANY
INCORPORATED
900 Market Street, Wilmington 99, Delaware

XP59-3



THERMOCOUPLES—Catalog 300, a 20-page publication, has been prepared to describe the Con-O-Clad mineral insulated thermocouples made by **Conax Corp., Dept. S/A, 2300 Walden Ave., Buffalo 25, N.Y.** Discussions of manufacturing and testing procedures are supported by illustrations.

Write in No. 382 on Reader Service Card

PRESSURE SWITCHES—A four-page bulletin briefly describing four series of pressure switches that trace pressure change through the negative rate of a disc-type sensing spring has been published by **Hydra-Electric. Dept. S/A, 3151 Kenwood, Burbank, Calif.** Switch design eliminates contact chatter and bounce and enables the switches to maintain positive settings in both high and low pressure systems.

Write in No. 383 on Reader Service Card

SWITCHING VALVE—The Series 19 acceleration switching servo valves for missile hydraulic control systems requiring reliable, compact and low weight servos have been described in Product Bulletin 106 by **Moog Servocontrols, Inc., Dept. S/A, East Aurora, N.Y.** The valves permit operation with fluid temperatures up to 600 deg F, and they feature high velocity gain.

Write in No. 384 on Reader Service Card

PNEUMATIC CONTROLS — Twenty motor, solenoid, pressure and manually actuated units for aircraft and missile applications are presented in the "Pneumatic Controls Bulletin PC1.20" by **Whittaker Controls Div., Telecomputing Corp., Dept. S/A, 915 N. Citrus Ave., Los Angeles 38, Calif.** The bulletin discusses selector valves, pressure regulators, shut-off valves, and other pneumatic components.

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LEAKPROOF PUMPS—Design features and model specifications for sealless "canned" pumps for leakproof pumping of corrosive, toxic, explosive, radioactive and other problem fluids are discussed in bulletin 1050-4 issued by **Fostoria Corp., Chempump Div., Dept. S/A, P. O. Box 25-27, Huntingdon Valley, Pa.** It is illustrated with cross-sectional photos, and contains drawings and charts.

Write in No. 386 on Reader Service Card

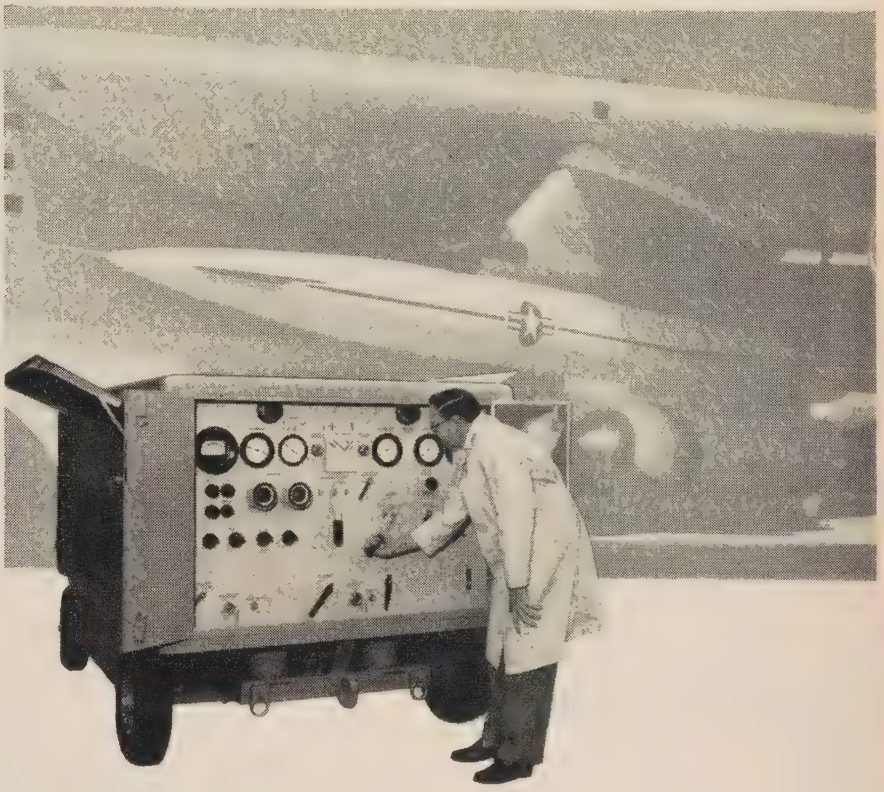
ANALYZERS—Nuclear magnetic resonance analyzers for hydrogen and fluorine compounds are discussed in a data sheet by **Schlumberger Well Surveying Corp., Ridgefield Instrumentation Div., Dept. S/A, Ridgefield, Conn.** Specifications and typical analysis chart are included.

Write in No. 387 on Reader Service Card

more on page 344

hma

COMPLETE CAPABILITY



GSE

Now in quantity production, Horkey-Moore-designed Ammonia Servicing Trailers will help SAC's Hound Dog equipped B-52Gs guard the peace of the '60s. Designed to a new modular concept, pioneered by Wright Air Development Center and North American Aviation, GAM-77 ground support equipment like this HMA trailer lowers costs and improves airborne readiness. Here's another instance where Horkey-Moore engineering ability and production experience have been called upon for advanced, reliable ground support systems for aircraft and missiles.

hma

horkey-moore associates

24660 Crenshaw Boulevard

Torrance, California / SPruce 5-1211

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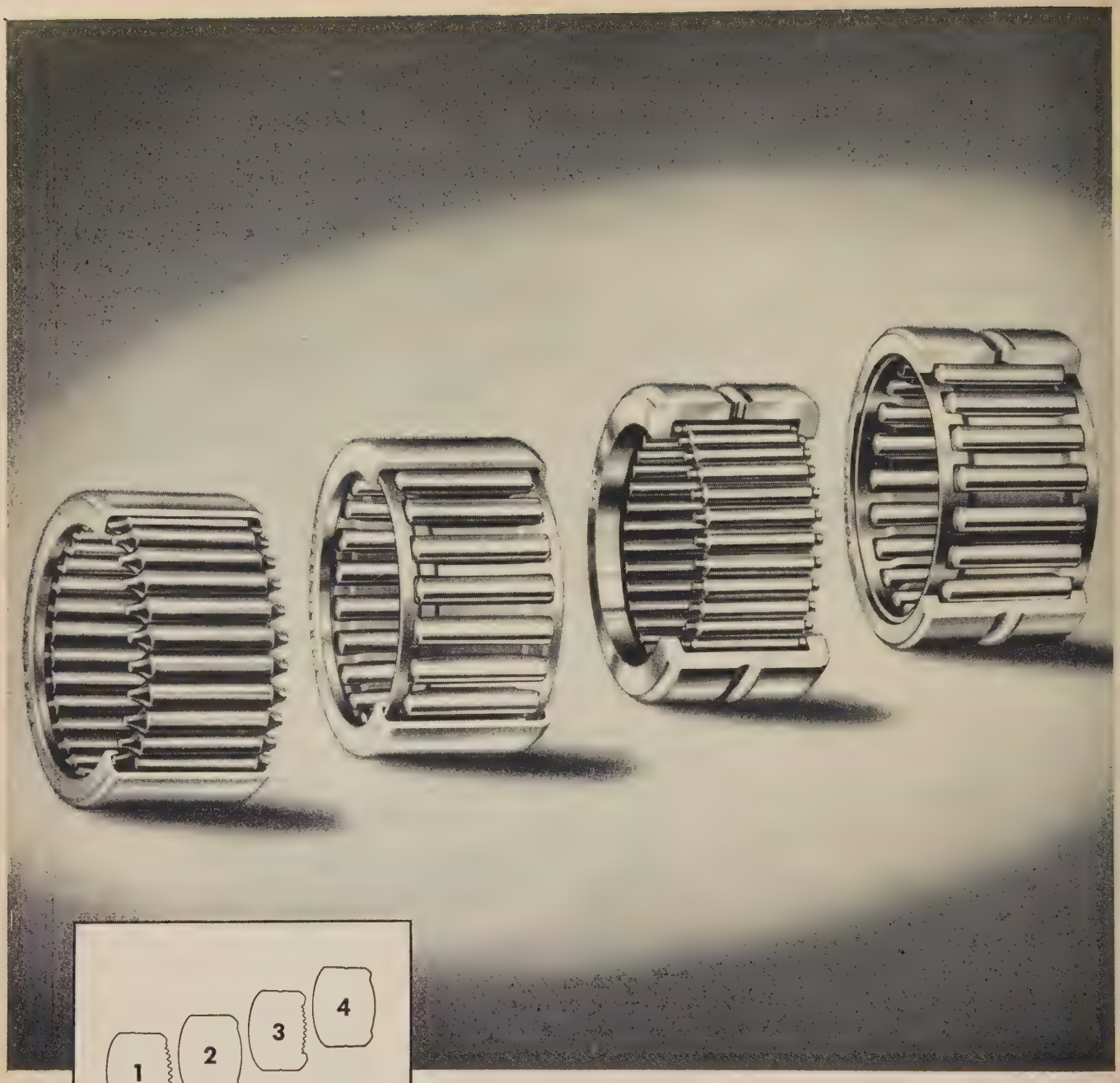

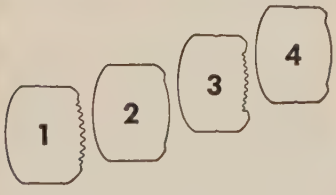

Torrington Drawn Cup Needle Bearing . .. for maximum radial capacity in minimum cross section . . . positioned by press fit—snap rings or shoulders unnecessary . . . runs directly on hardened shaft . . . most compact, light weight, economical.

Torrington Drawn Cup Roller Bearing . . . for higher speeds or long pregreased life . . . thin section race for simple press fit . . . runs directly on hardened shafts . . . unit construction for easy assembly . . . shaft-riding retainer.

Torrington Heavy Duty Needle Bearing . . . for use with thin section or split housing where extreme impact loads require heavy outer race . . . maximum shock resistance . . . full roller complement . . . unit construction.

Torrington Heavy Duty Roller Bearing . . . for combination of high speed, long pregreased life or shock resistance . . . roller stability provided by end-guiding . . . flange-riding retainer . . . unit design.

All of these types of bearings are available with inner races.

Only Torrington Makes All Four!

Torrington developed the Needle Bearing and its specialized variations. This breadth of experience assures impartial engineering recommendations based on specific application requirements. You can rely on Torrington to recommend the most compact and economical design compatible with operating conditions and performance requirements. Call on your Torrington representative for help in applying the right bearing in the right place. **The Torrington Company, Torrington, Conn.—and South Bend 21, Indiana.**

TORRINGTON BEARINGS

Every Basic Type of Anti-friction Bearing

NEEDLE • SPHERICAL ROLLER • TAPERED ROLLER • CYLINDRICAL ROLLER • NEEDLE ROLLERS • BALL • THRUST

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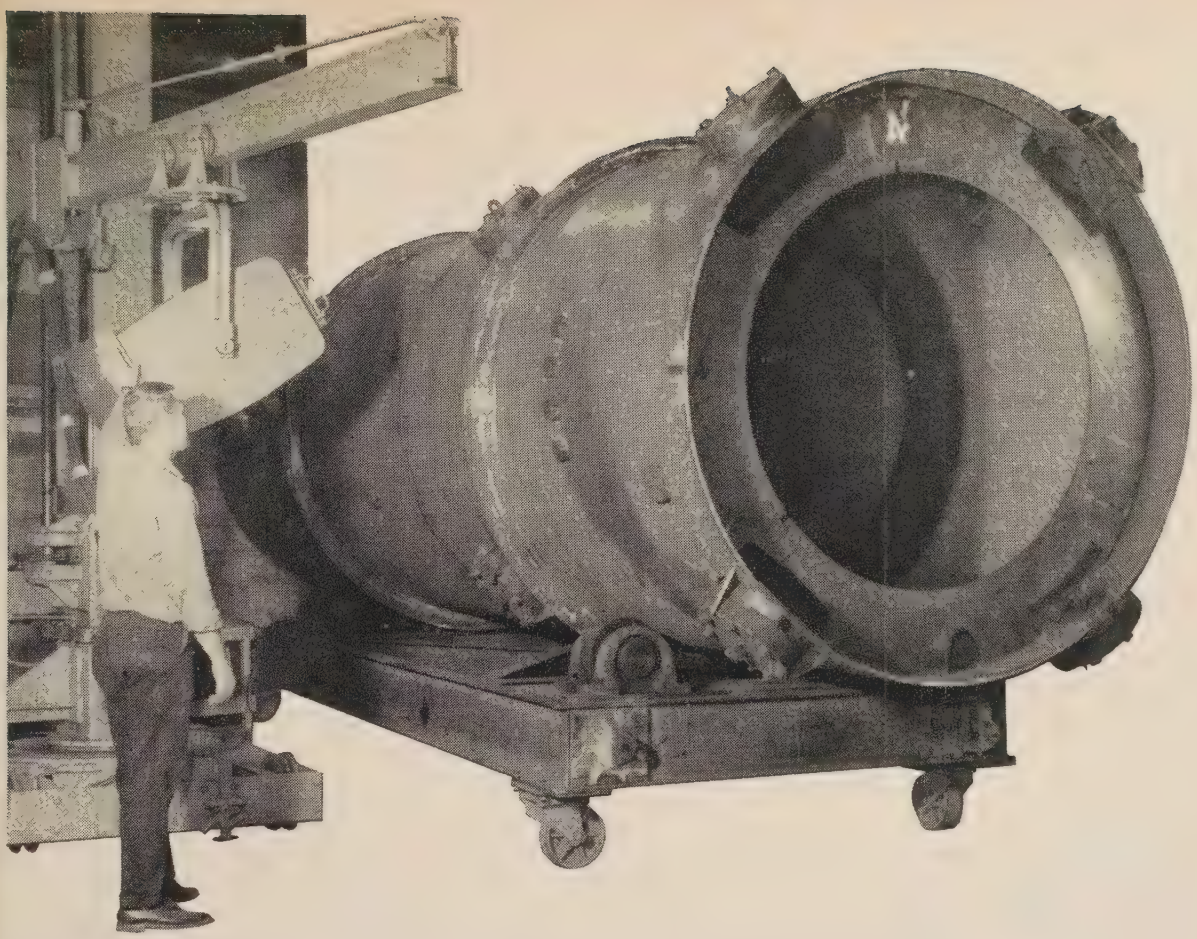


Undersea nest for a talented metal bird

This is the firing tube of the Navy's Polaris missile, made by Consolidated Welding and Engineering Company, Chicago, Ill. Every weld must be flawless. To make sure, more than 100 radiographs are made on each assembly.

Made of HY-80 plate with monel inserts, this firing tube presents difficult problems in welding dissimilar metals. But radiography, with Kodak Industrial X-ray Film, Type AA, checks the entire assembly for discontinuities.

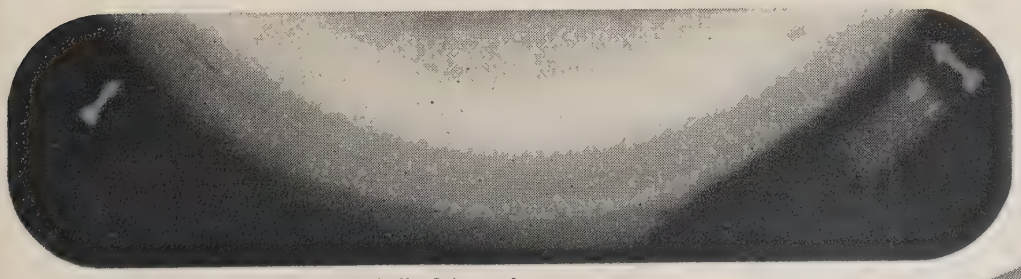
Radiography provides the means of "seeing" internal conditions and supplies a lasting record of what is seen. It gives producers of welded products and of castings a means of making sure only high-quality work is delivered.

Would you like to know how radiography can help you? See an x-ray dealer or write us to have a Kodak Technical Representative call.

Read what Kodak Industrial X-ray Film, Type AA, does for you:

- Speeds up radiographic examinations.
- Gives increased detail visibility and easy readability at all energy ranges . . . because of high film contrast.
- Provides excellent uniformity.
- Reduces the possibility of pressure desensitization under shop conditions.

EASTMAN KODAK COMPANY
X-ray Division, Rochester 4, N. Y.



Kodak
TRADE MARK

Radiograph of weld on missile firing tube.

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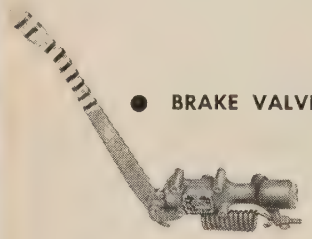
RELIABILITY AND PERFORMANCE

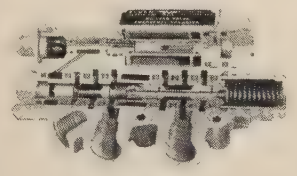
are our main products

First, imaginative design; then experienced thoroughness through development, tooling, production, assembly and tests, all under strict quality control in an unusually well equipped plant . . . we can help you solve your special problems . . .

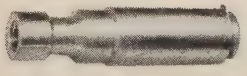


- BRAKE VALVES

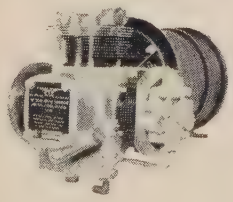
- TRANSFER VALVES



- RELIEF VALVES



- COMPACT COMPRESSORS



also

- SOLENOID VALVES
- SELECTOR VALVES
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SERVO ACTUATOR—A compact electromechanical linear actuator for closed-loop positioning systems has been described in Product Data 111-12, a data sheet available from **Lear, Dept. S/A, 110 Ionia Ave., N.W., Grand Rapids 2, Mich.** The Series 3107 servo actuator has been used to position gimbal-mounted rocket engines.

Write in No. 388 on Reader Service Card

SOLENOID LOCK—Dimension drawing and a photograph of a typical installation of a solenoid locking mechanism for standard Esco-type JR rotary switches are contained in Bulletin 18, available from **Electro Switch Corp., Dept. S/A, King Ave., Weymouth, Boston 88, Mass.** Data on solenoid ratings are also included.

Write in No. 389 on Reader Service Card

ALLOY CASTINGS — Static castings, centrifugal castings and shell molded castings are discussed in bulletin No. G-159 prepared by the **Duraloy Co., Dept. S/A, Scottdale, Pa.** It includes technical data on physical properties, corrosion, heat, and abrasion resistance, as well as standard designation and stress temperature curves for selected high alloys.

Write in No. 390 on Reader Service Card

CIRCUIT BREAKERS — Molded case circuit breakers are described in bulletin GEA-7070 issued by **General Electric Co., Dept. S/A, 90 Whiting St., Plainville, Conn.** It provides selection, application, ordering information, illustrations and outline drawings.

Write in No. 391 on Reader Service Card

CLUTCH—The Series 878 magnetic-particle clutch, a device capable of easily controlled, high-response operation in closed-loop positioning servo systems, has been described in Product Data 110-7, a data sheet available from **Lear, Dept. S/A, 110 Ionia Ave., N.W., Grand Rapids 2, Mich.** The device can be used for low inertia absorption dynameters, brakes, disconnects, etc.

Write in No. 392 on Reader Service Card

ENGINE STARTER—Both fuel-air combustion and air turbine starting can be handled by the Type 36E73-2A fuel air starter, according to Publication 36U-6-94A, issued by **Utica Div., Bendix Aviation Corp., Dept. S/A, 211 Seward Ave., Utica, N.Y.** The four-page bulletin states that the device is capable of reliable and consistent performance through 1000 start cycles.

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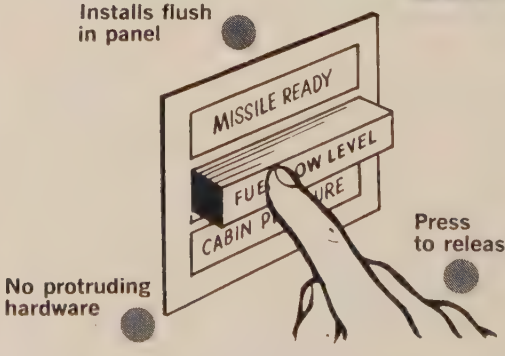
Electronically Controlled Display Systems

compact — flush-fitting

FUEL LEVEL LOW	UTILITY HYDRAULIC
FUEL BOOST PUMP FAIL	LEFT FUEL
NO. 1 GENERATOR OUT	RIGHT GENERATOR
NO. 2 GENERATOR OUT	FLIGHT HYDRAULIC
HYD. SYSTEM OUT	LAUNCHER PREPARED
AUTO PITCH OUT	ARM/FUZ
HATCH UNSAFE	MISSILE PREPARED
LH PITOT OFF	MISSILE AWAY
RH MAST OFF	SELF-CHECK COMPLETE



Compact, tandem designs allow stacking vertically in rows to save weight and space. Nomenclature can be provided to specific requirements. Control components can be integral with light modules.

RADAR RELAY INC.

2322 Michigan Avenue, Santa Monica, California / UPton 0-1526 / EXbrook 4-2230

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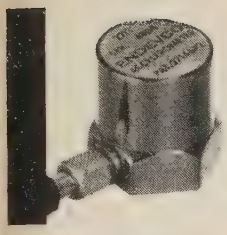

FORD VIBRATION INSTRUMENTATION: The Ford Motor Company entered the experimental gas turbine engine field in 1952. The Ford Turbo Machines Department is now engaged in research and development of a turbine engine and a working model has been tested in a tilt-cab truck. An obsolete engine, the Ford 702, has developed 160 horsepower at shaft speeds up to 36,000 rpm. ■ A new supercharged 300 horsepower turbine engine was recently announced by Ford Engineers. Known as the "704," the engine weighs 650 pounds installed, compared to 2,700 pounds for a truck diesel engine of comparable horse-

ENDEVCO TRANSDUCERS SOLVE VIBRATION ANALYSIS PROBLEM

power. The engine has two stages of compression, each operating at a 4:1 pressure ratio. Two burners are used for driving the dual compressors, the low speed wheel turning at 46,500 rpm and the high speed wheel at 91,500 rpm.

THE PROBLEM: The Ford Test program requires a wide variety of instruments to measure, control and record performance data of component parts. Measurement of vibration, for example, is a critical factor in this program. Vibrations that may cause metal fatigue, oil film breakdown, overheating, etc., are discovered during tests on individual engine "stands."

THE SOLUTION: Ford engineers use a total of six Endevco Series 2200 Accelerometers providing frequency responses up to 6,500 cycles per second. The accelerometers are connected to bearing test rigs, for example (see photo). The accelerometers relay measurements of acceleration movements in turbine shafts from three coordinates (radial vertical, radial horizontal and axial). Temperatures of the metal housings to which the standard Endevco transducers are attached average up to +150°F. Temperatures at which the water-cooled, heat-resistant models are used range up to +1000°F or more. The large self-generated output of the Endevco accelerometers eliminates the need for additional stabilization of a power supply.

THE RESULTS: The Endevco transducers are attached with a single-pole threaded bolt. The signal is fed through an Endevco amplifier to an oscilloscope or panoramic analyzer. The analyzer concentrates on a small section of the total signal and may present from 4 to 10 harmonic vibrations of different frequencies being fed from the unit at one time. This analyzer separates the frequency bands into individual bands, which it then sweeps from 20 to 40,000 cycles every second, measuring the frequency and amplitude in millivolts. ■ Ford Technicians convert these vibration records by mathematically integrating acceleration with respect to time to obtain the displacement or housing vibration. Thus, they locate the sources of objectionable resonance and take steps to eliminate or reduce vibration in the overall design. ■ Endevco accelerometers have also served as pickups for determining spring rate and damping characteristics of rubber bonded bearings. • **ENDEVCO CORPORATION** • 161 EAST CALIFORNIA BOULEVARD PASADENA, CALIFORNIA • PHONE SYCAMORE 5-0271

Close-up shows two Endevco Accelerometers on bearing test rig in Ford Instrumentation Section, Dearborn, Michigan. Cable passes to Endevco Amplifier (not shown on right).

Write in No. 251 on Reader Service Card at start of Product Preview Section

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- base polymer employed • quality numbers
- colors • finishes • standard thicknesses
- widths available • Shore A hardness values
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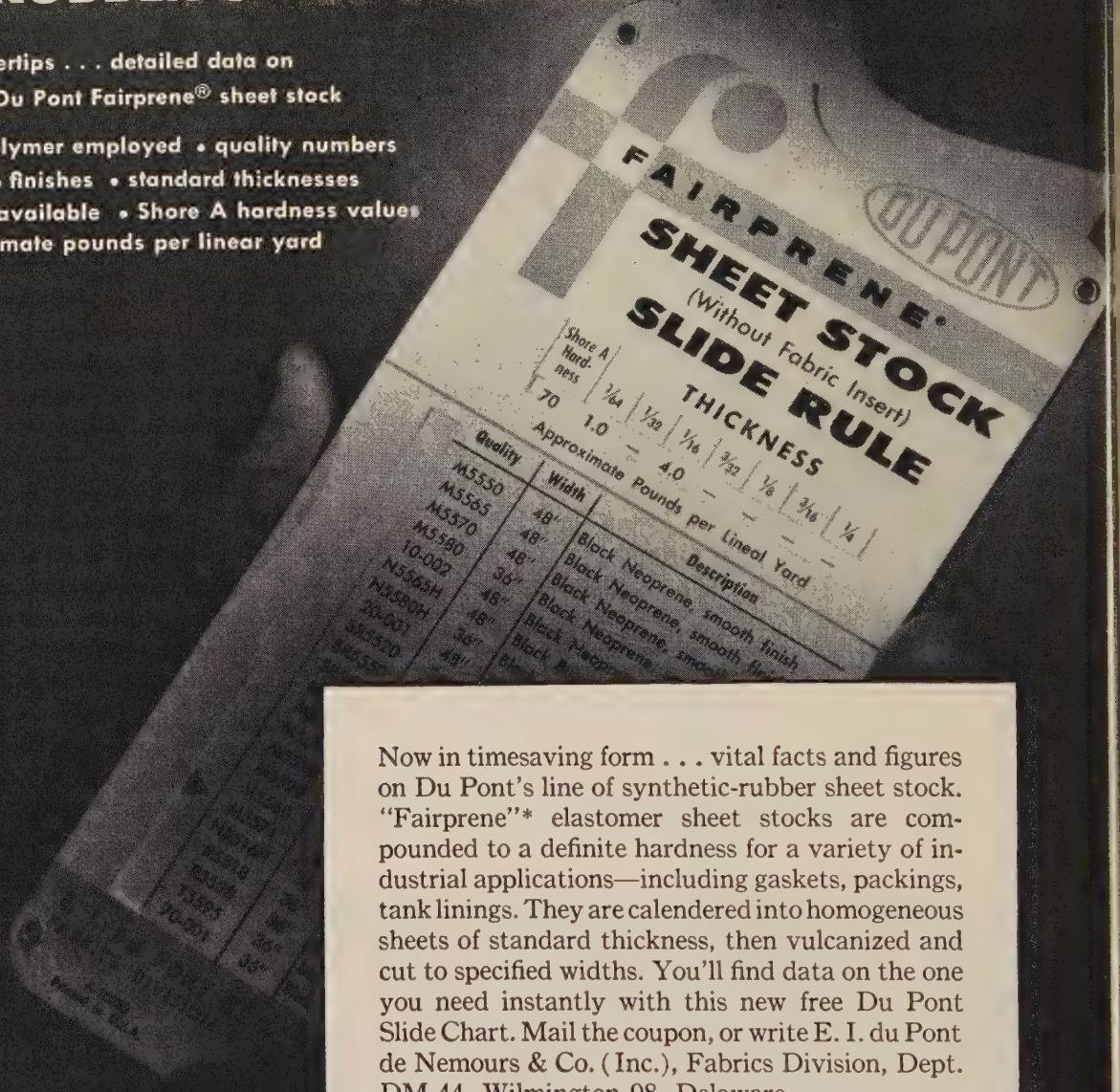

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* Fairprene" is Du Pont's registered trademark for its coated fabrics, sheet stocks and cements.

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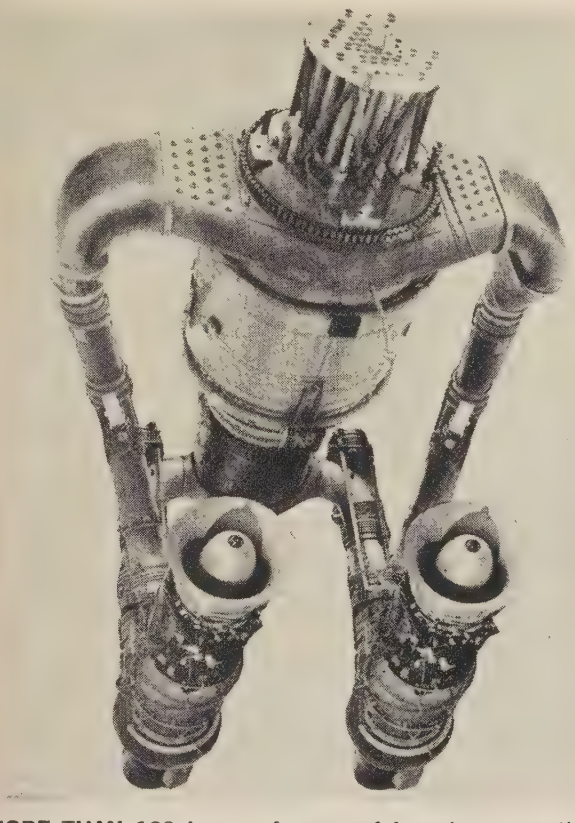
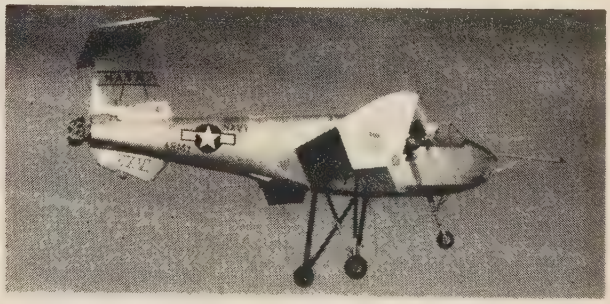
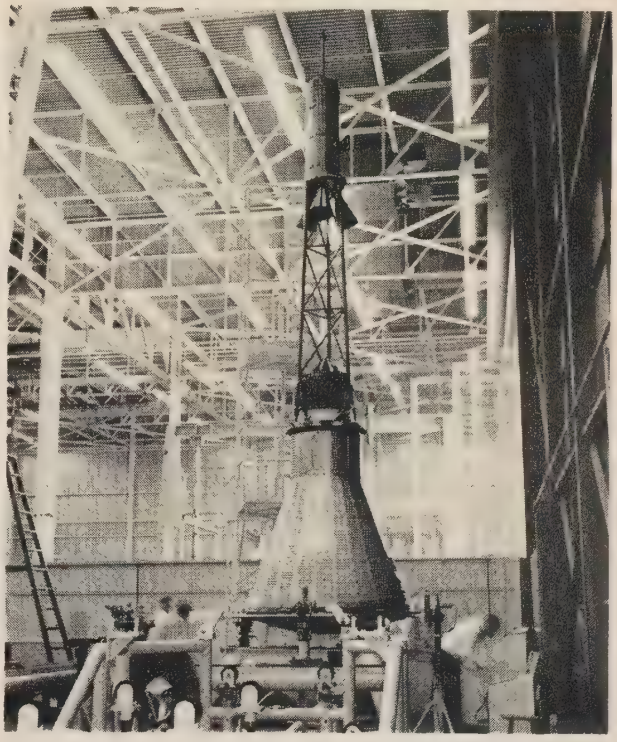


MORE THAN 120 hours of successful nuclear operation are claimed by GE for its "Heat Transfer Reactor Experiment 3," consisting essentially of a reactor and two GE j47 turbines. In tests at AEC's Idaho Falls, Idaho, facility, everything went according to plan, says GE, including 65 hours' continuous operation. The ultimate goal of the HTRE-3 development program is a direct-air-cycle nuclear turbojet.

MERCURY CAPSULE NO. 1 has been delivered to NASA by McDonnell. The first of 20 capsules on order, it was finished less than 14 months after McDonnell got the Mercury contract.



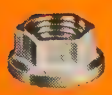
HOVERING flight at zero airspeed and altitudes from 100 to 3700 ft, near-vertical takeoffs after only 30 ft of ground roll at ground speeds of 22 knots, and landings at 17 knots were performed by Vertol's VZ-3RY research plane before it crashed recently.



Melpar, a subsidiary of Westinghouse Air Brake, set up a Plasma Physics Branch at its Physical Science Lab., Falls Church, Va. Under the direction of R. C. Jones, the new group will do experimental and theoretical work. . . . **Systems Division,** of Beckman Instruments, Anaheim, Calif., formed a new research group to study advanced information-handling. Robert R. Pintar, formerly of Thompson Ramo Wooldridge, heads the group. One of the unit's first projects will deal with methods of measuring the performance of large instrumentation complexes. . . . **Aero Industries,** Boyertown, Pa. a new company formed to take over four existing firms and most of the stock of a fifth, will engage in manufacture and distribution of gas turbine engines. The companies involved are Atlantic Aviation, its subsidiary Montgomery Enterprises, and its 80 percent subsidiary Wellington Packaging Machinery, as well as Jacobs Aircraft Engine and Penn Airways.

MK3031

MF1400



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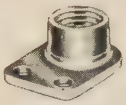

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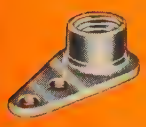

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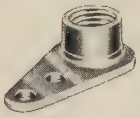

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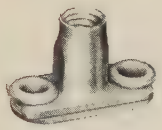

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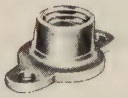

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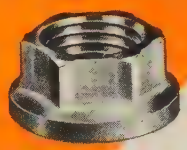

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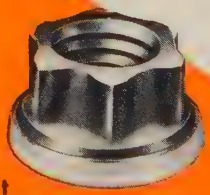
Hi-Temp Engine nut



"Captive Washer" nut

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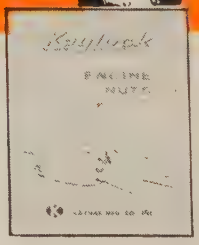

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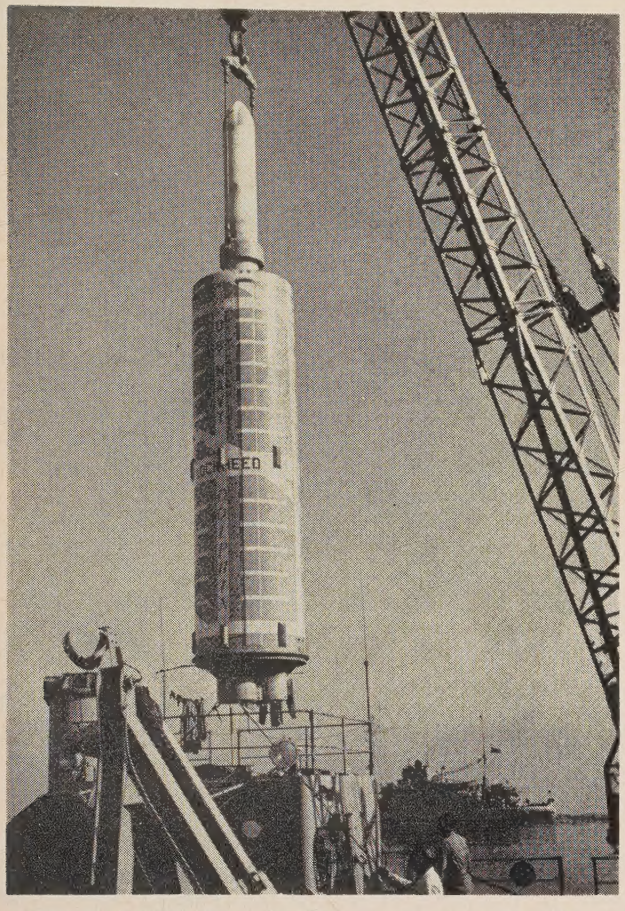
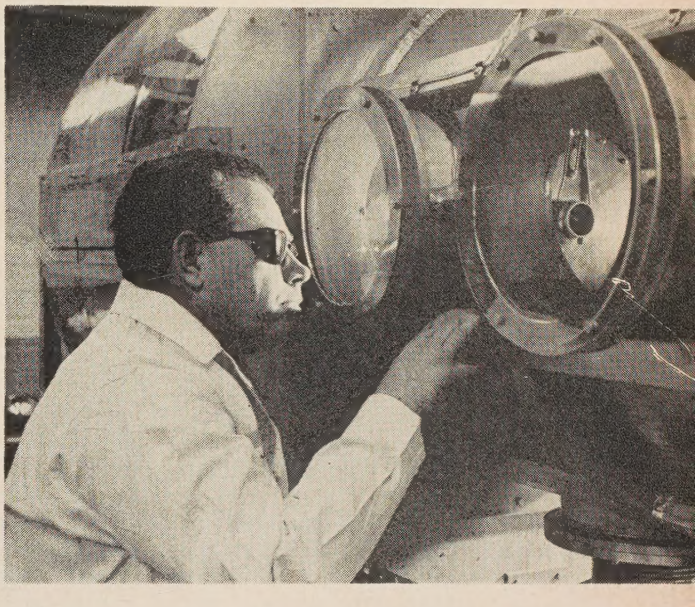
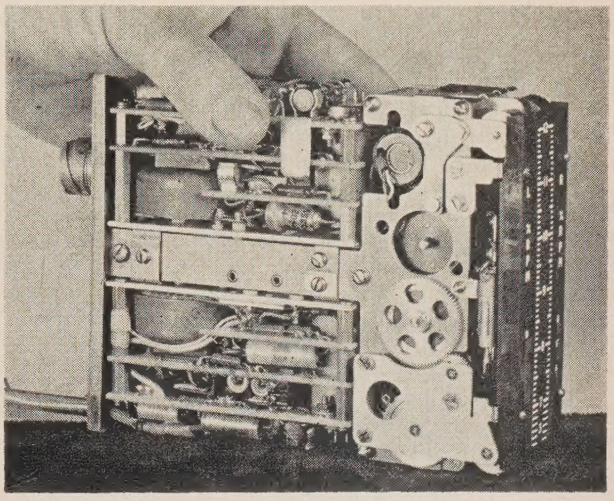


FIRST LAUNCHINGS from submerged subs in the Polaris program will be made with full-scale Dolphin dummy missiles. A conical interstage fairing (not shown) covers up the lower half of the second stage.

EXPERIMENTAL plasma engine at Republic is being watched on its first run. The spacecraft powerplant could be used for course and attitude corrections.





ENGINE SPEED, fuel flow rate, and exhaust gas temperature are displayed on the same new instrument by GE. The presentation was worked out for use on the low-flying Grumman A2F-1 jet.

A. V. Roe Canada Aeronautical Group has established an office in Los Angeles. It is headed by William R. Stephens, technical sales manager for the U. S. The group includes Avro Aircraft, Orenda Engines, Canadian Applied Research, and Canadian Steel Improvement. . . . **Bethlehem Foundry & Machine,** Bethlehem, Pa., organized an Environmental Engineering Division to furnish services and products to companies in the electronics and missile fields. . . . **Electronic Engineering** Co. of California and its production subsidiary Engineering Electronics, both of Santa Ana, Calif., have purchased a 25 per cent interest in Sipican, Marion, Mass., and made an agreement with Francis Associates, also of Marion, inventors of the MiniWeld process. EECo is the first West Coast manufacturer to use the MiniWeld electronic construction technique.

Solving your writing "predicament"

by B. D. Jamanr, Mechanical Engineering, Firestone Engineering Laboratory*

TODAY'S ENGINEER is being gunned by critics who express their distaste for the way in which he writes. They maintain that his technical prose should be as clear and effective as that of Hemingway.

Most of these self-styled critics are the supporting personnel who manage the administrative and nontechnical affairs of the engineer. To serve the many needs of the engineer, these supporting personnel often have to read what the engineer writes. Perhaps they don't have to grasp the technical content, but they do have to know what it represents in dollars, time, materials, etc.

So, really, the people who point the gun of criticism at the engineer are justified in one respect. They have good reason to criticize if, in trying to do their jobs, they fail to understand what the engineer is saying because of his so-called hazy and ineffective writing.

Faced with this mounting criticism, the engineer finds himself in a predicament. The only way out lies in himself. If he is to improve his writing, he has to be his own analyst, editor, and teacher. But the engineer must overcome a big obstacle first. That obstacle is he himself, because he is his own worst enemy when it comes to analyzing and improving his own writing.

There are many in engineering who are convinced that a flowery, long-winded, heavy-worded style is the mark of the engineering intellect. They look upon this style as a status symbol, and firmly believe it will guarantee them a higher foothold in the long climb to the top of their profession. The engineer also supposes that his own writing is measured by other people on the basis of the "superior" vocabulary he displays.

Couldn't be farther from truth

No two suppositions could be farther from the truth. Their application completely bogs down engineering thinking in a swamp of words. But the engineer has built his "literary" wall with these two theories as foundation blocks. And he will defend his wall with as many modifiers as he can muster!

What the engineer must realize is that his writing, like his slide rule, is a means to an end. It is a tool that he can use very effectively to further his career so long as he learns how to use it properly. But in developing its use, he has to turn to his inner self and also develop the rigid discipline that he must practice if he is to become a better writer.

To help his own cause of self-discipline and improvement in writing, the engineer must cultivate certain habits. Some of these may be forgotten habits that lie dormant within him. Others may be familiar. Nevertheless, he must acquire them if he wishes to write more clearly and effectively. Here are three habits that can help you to improve your writing:

• *Accept personal criticism* in its true light, instead of jumping to the conclusion that it is a means of "shooting you down." Here is a long-winded passage:

> "The proven stability of rubber eliminates the need for maintenance over the time period and under the conditions anticipated for this application."

The author of this sentence should accept the fact that he is long-winded when he realizes that he could say the same thing more effectively in fewer words:

> "Since rubber is stable, it requires no maintenance in this application."

• *"Weed out" useless words* that crowd out your real thoughts. In the following example, the words in italics should be "pulled," since they only detract from the true meaning of the sentence:

> "*It can be seen that* the missile will not be damaged in the support area because *this is due to the fact that* side loads are less severe."

• *Give "action" to your sentences.* Verbs are the "prime movers" of sentences, therefore rely on them and not on nouns, and make them active whenever you can. The italicized passages in this sentence are "inactive":

> "The test results *give an indication* the *completion* of the cost estimate *will not be achieved* before the state of the fabrication of the model."

Here is the same sentence written around its verbs:

> "The test results indicate that the cost estimates will not be completed before the fabrication of the model is started."

Contributions to this department may be on any subject technical or nontechnical, about which readers would like to air their views. Names and professional affiliations will be withheld on request.

* Firestone Engineering Laboratory, Monterey, Calif.

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